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INSTRUMENTATION AND FLIGHT REPORT ON ASTROBEE 1500 FLIGHT 16.02 GT

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FEBRUARY 1968

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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SUMMARY

On 21 October 1964 the Sounding Rocket Branch of Goddard Space Flight Center (GSFC) launched Astrobee 1500 Flight 16.02 GT from Wallops Island, Virginia. This was the second NASA-conducted test flight, preparatory to adoption of the Astrobee into the National Sounding Rocket Program as eventual replacement for the Argo D-8 Journeyman. Fully instrumented for performance evaluation by the Sounding Rocket Instrumentation Section, all major Flight 16.02 objectives were accomplished and represented the first successful flight for this type vehicle.

This report documents the operation and installation of the Flight 16.02 instrumentation, briefly discusses that of Flight 16.01, and examines the electronic systems involved. Representative calibration curves, sample antenna radiation patterns, and vehicle electrical system checkout procedures, and prelaunch and countdown preparations are included in appendices.

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INSTRUMENTATION AND FLIGHT REPORT ON ASTROBEE 1500 FLIGHT 16.02 GT

INTRODUCTION

Early in 1962, the Sounding Rocket Branch of Goddard Space Flight Center (GSFC) undertook an evaluation program to select a replacement for the Argo D-8 Journeyman rocket for which it had become increasingly difficult to obtain Sergeant XM-20 first-stage motors. After a survey of available vehicles of comparable performance, the Astrobee 1500 was chosen as a suitable successor. Further, the Astrobee 1500 was less expensive, had more inherent reliability, because of two fewer stages, and could provide an improved payload environment. As this relatively new vehicle had a somewhat erratic flight history, a flight test program was initiated to confirm rocket performance, define precise payload environment, and establish the reliability of vehicle subsystems.

The Astrobee 1500 sounding rocket is an unguided, two-stage, solid-propellant vehicle designed to carry net payload weights ranging to 300 pounds. It will deliver a 75-pound payload to an altitude of about 1397 nautical miles when launched at an elevation angle of 80 degrees. Figure 1 shows an Astrobee 1500 mounted on its boom-type launcher.

In this report are described the functions of the National Aeronautics and Space Administration (NASA) GSFC Sounding Rocket Instrumentation Section in support of the Astrobee 1500 Flight 16.02 GT, launched from Wallops Island on 21 October 1964.

The primary purposes of this heavily instrumented flight were to evaluate rocket performance and payload environment, in addition to verifying design changes incorporated as a result of unsuccessful Flight 16.01 GT. Specifically, the basic flight objectives were to:

1. Confirm the performance of the Astrobee 1500 rocket, and the operation of vehicle subsystems, in order to assess their usefulness in the Sounding Rocket Program.

2. Define the flight environment to which the payload will be subjected, including: interior temperatures, sustained longitudinal and lateral acceleration, and vibrational and rotational accelerations.

3. Determine second stage tipoff and its resulting dispersion.

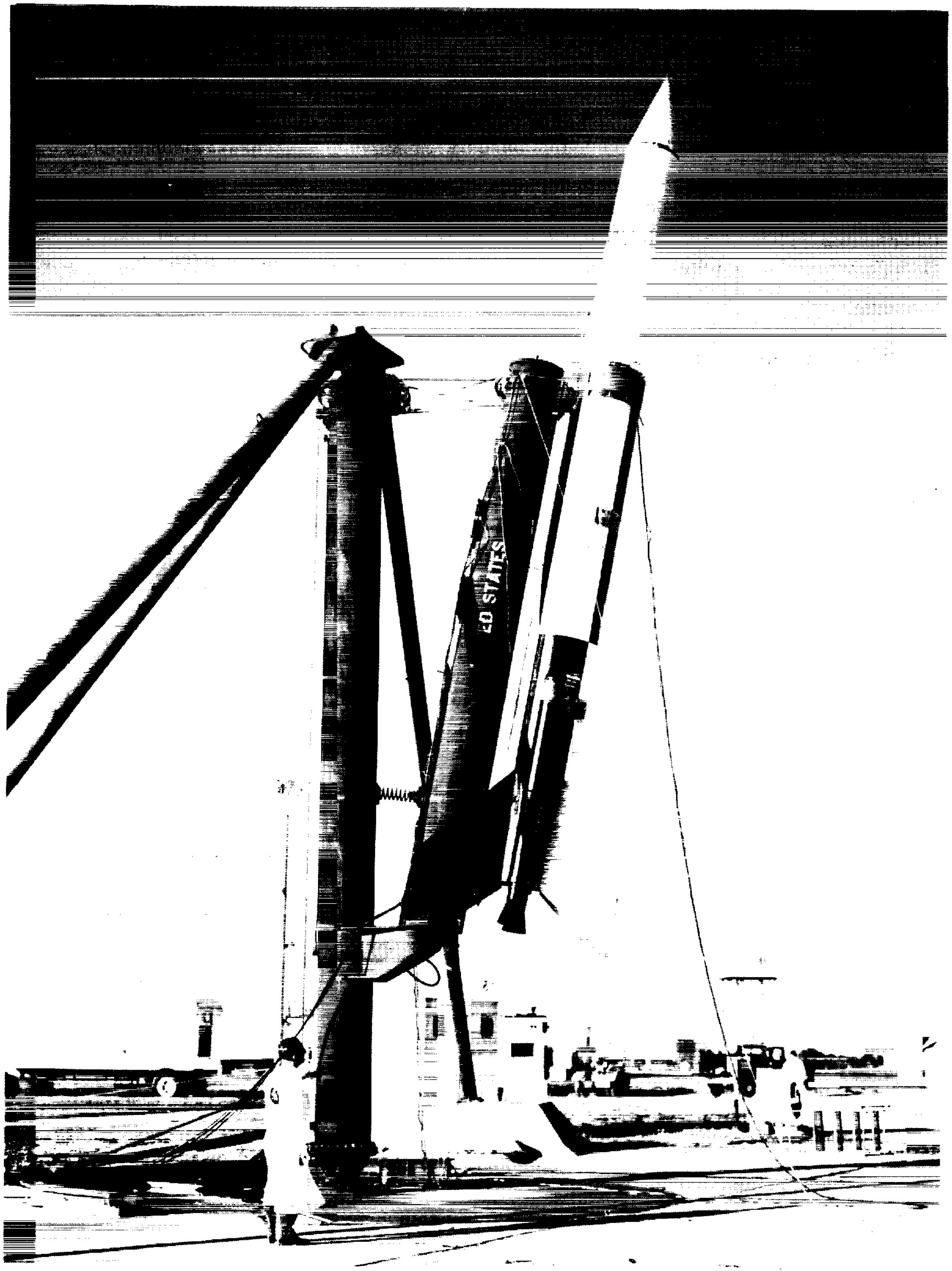


Figure 1. Astrobee 1500, Flight 16.02, on Launcher

4. Verify the capability of Wallops Island, AN/FPS-16 and S-band (Spandar), radars to skin track a high-performance vehicle using aluminized propellant, and to compare the results with the tracking of an onboard C-band radar transponder.

5. Confirm the ability of the rocketborne telemetry and antennae system to transmit inflight data, both to main base and to various downrange receiving stations.

GENERAL DESIGN

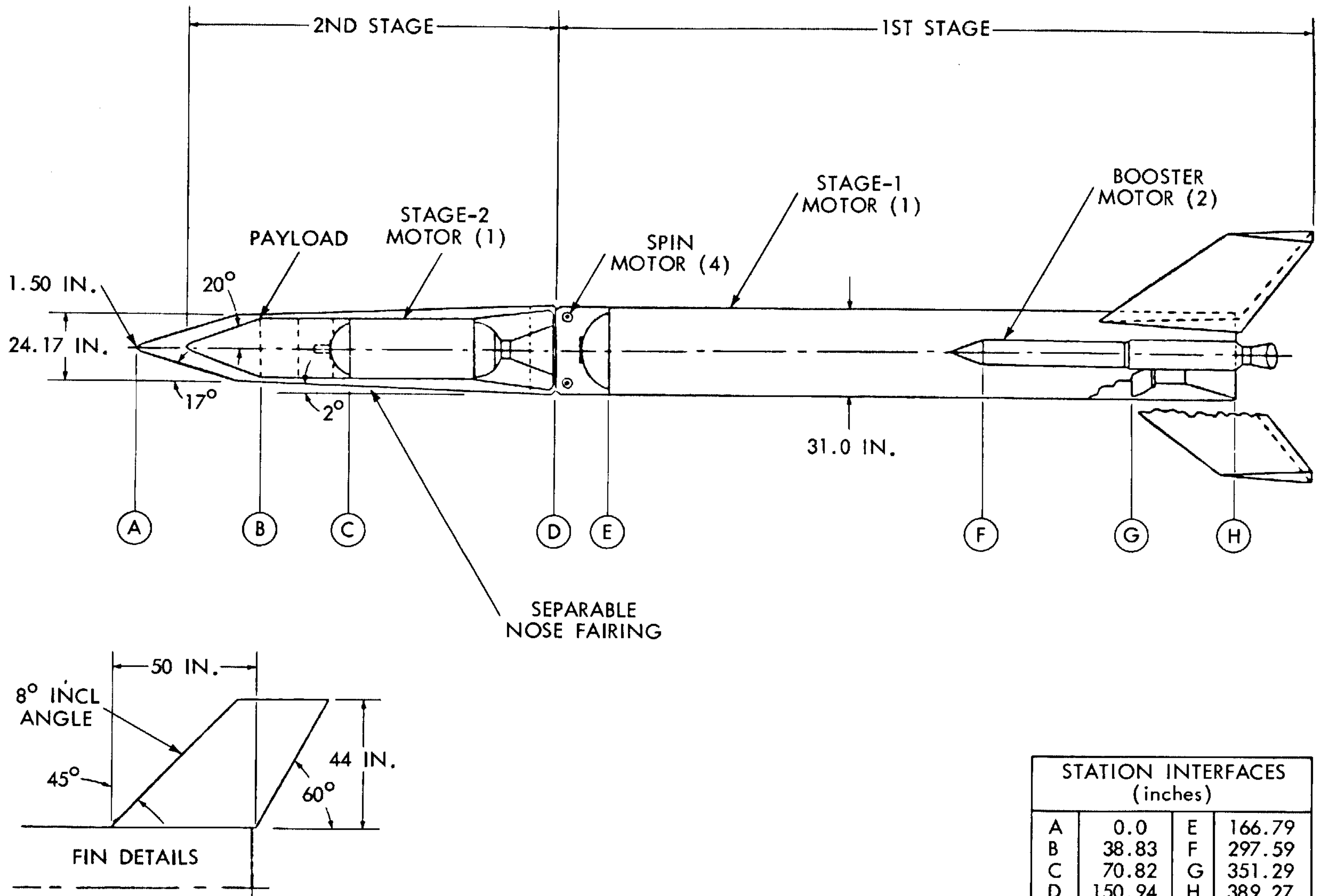
An Aerojet-General Corporation (AGC) 28KS-57000 (Junior) solid-propellant motor serves as the primary Stage I propulsion unit. Two side-mounted, Thiokol 1.5 KS-35000 (Recruit), boosters provide short duration assist-thrust to increase initial acceleration. Stage I aerodynamic stability is provided by four single-wedge fins (see Figure 2), with a platform area of 12.42 square feet. Fins are canted to give a final first-stage roll rate of 2.2 revolutions per second.

Bolted to the forward end of the Stage I motor is an Interstage structure which supports a spin table. Four Atlantic Research Corporation (ARC) 1KS-210 motors drive the spin table, and attached Stage II assembly, to an absolute rotational velocity of 12.5 revolutions per second. These spin motors are ignited during the coasting period between Stage I burnout and Stage II ignition.

Stage II thrust is supplied by an AGC 30KS-8000 motor. Stage II is covered by a nose fairing which is hinged at the forward end of the Interstage structure, and secured with explosive-bolt actuated clamps. This fairing acts as a heat shield to protect Stage II and the payload from aerodynamic loads and heating during Stage I boost, thereby eliminating the necessity for extensive insulation and shielding. Explosive bolts are fired to open the fairing in clamshell fashion prior to Stage II ignition.

PERFORMANCE CHARACTERISTICS

Because of the boom type launcher employed, a relatively high initial acceleration is required to produce sufficient velocity for rocket stability. Immediately after Stage I ignition, the acceleration attains about a 10.9g force, with a resultant velocity of 526 feet per second at 1.6 seconds. The Stage I motor burns for 40.1 seconds and develops an average thrust of 51,870 pounds. This is augmented by two boosters, which burn for 2.4 seconds, and develop an average thrust of 36,000 pounds each.



STATION INTERFACES (inches)			
A	0.0	E	166.79
B	38.83	F	297.59
C	70.82	G	351.29
D	150.94	H	389.27

Figure 2. Astrobee 1500, General Arrangement

Assuming an effective launch elevation of 80 degrees and a net payload of 135 pounds, as was the case of Flight 16.02, the sequence of major flight events and rocket trajectory are as listed in Table 1, and shown in Figure 3.

Table 1
TYPICAL MAJOR FLIGHT EVENTS OF AN AEROBEE 1500

EVENT	TIME (Sec)*
Stage I Motor Ignition	0.0
Booster Motors Ignition	0.1
Booster Motors Burnout	2.4
Stage I Motor Burnout	40.1
Spin Motors Ignition	48.0
Nose Fairing Open	49.5
Stage II Motor Ignition and Stage I Separation	50.0
Stage II Motor Burnout	80.0
Apogee	882.0
Impact	1850.0

*Assuming a payload weight of 135 pounds and a launch angle of 80°.

Stage II weight is 1134 pounds at ignition and, during the 30-second burnout time, develops an average thrust of 8460 pounds. The nose fairing opens at 175,133 feet, while apogee is at 1142 nautical miles, and downrange impact distance is 1364 nautical miles.

HISTORY OF FLIGHTS

Two Astrobee 1500 rockets had been flight tested subsequent to the NASA/GSFC flight test program. For flight performance, the Air Force Cambridge Research Laboratories provided instrumentation for these vehicles, while the

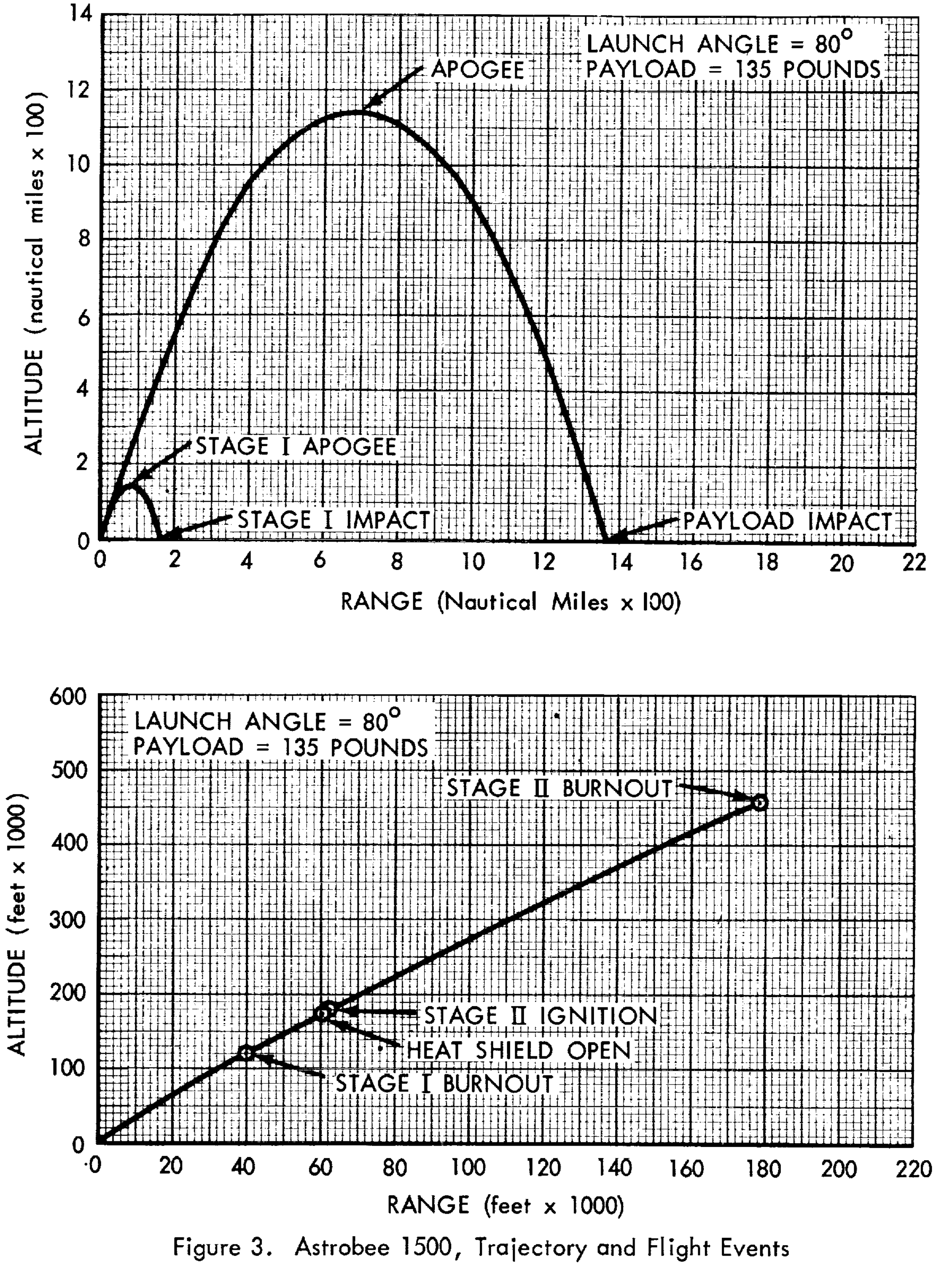


Figure 3. Astrobee 1500, Trajectory and Flight Events

Pacific Missile Range provided ground support, launch, and tracking facilities. Launched from the Naval Missile Test Facility at Point Arguello on 1 August 1961, the first flight became unstable at T+22.6 seconds and underwent complete structural failure. Examination of recovered Stage I hardware uncovered the apparent cause as a burn-through of the Stage I exit cone. Static tests later showed that coating the exit cone with Rokide provided the required thermal protection.

A second Astrobee 1500 performance flight, instrumented and launched by the same agencies, was apparently successful, although telemetry and radar tracking were lost soon after Stage II ignition. Flight success was established on the basis of the sighting of three geodetic flares ejected around apogee at about the predicted points in space. It is speculated that transmitter and beacon failure was caused by vacuum tube failure, due to the vibration and/or thrust forces experienced.

On 9 July 1962, a third Astrobee was launched from Point Arguello, for the Sandia Corporation. The primary purpose of this night launching, however, was to carry a scientific experiment, and not performance instrumentation. Breakup of the vehicle occurred at T+16.5 seconds, with indications of buffeting and unusual vibrations commencing at T+7 seconds. On the basis of indicated flight anomalies, structural modifications were made to strengthen various areas of the Astrobee Stage II.

FLIGHT 16.01

In late 1962 the Sounding Rocket Branch of GSFC received an Astrobee 1500 rocket to be instrumented for flight performance evaluation. This rocket, Flight 16.01, was launched from Wallops Island on 8 April 1963.

16.01 INSTRUMENTATION. The Flight 16.01 instrumentation and telemetry payload, designed and fabricated by the Sounding Rocket Instrumentation Section (SRIS) personnel, is shown in Figure 4, while undergoing dynamic balance tests. Two FM/FM telemetry systems provided a total of 28 channels of inflight performance and environmental data. Table 2 identifies the various data with the associated IRIG bands.

Each telemetry system employed a 10-watt Vector model TUFT-10 transmitter and a pair of quadraloop antennas. In addition, an AN/DPN-73 C-band radar beacon was carried to allow precise payload tracking. The beacon radiated 400 watts on 5600 MHz, and had a receiver frequency of 5486 MHz. Total payload weight was 104.3 pounds.

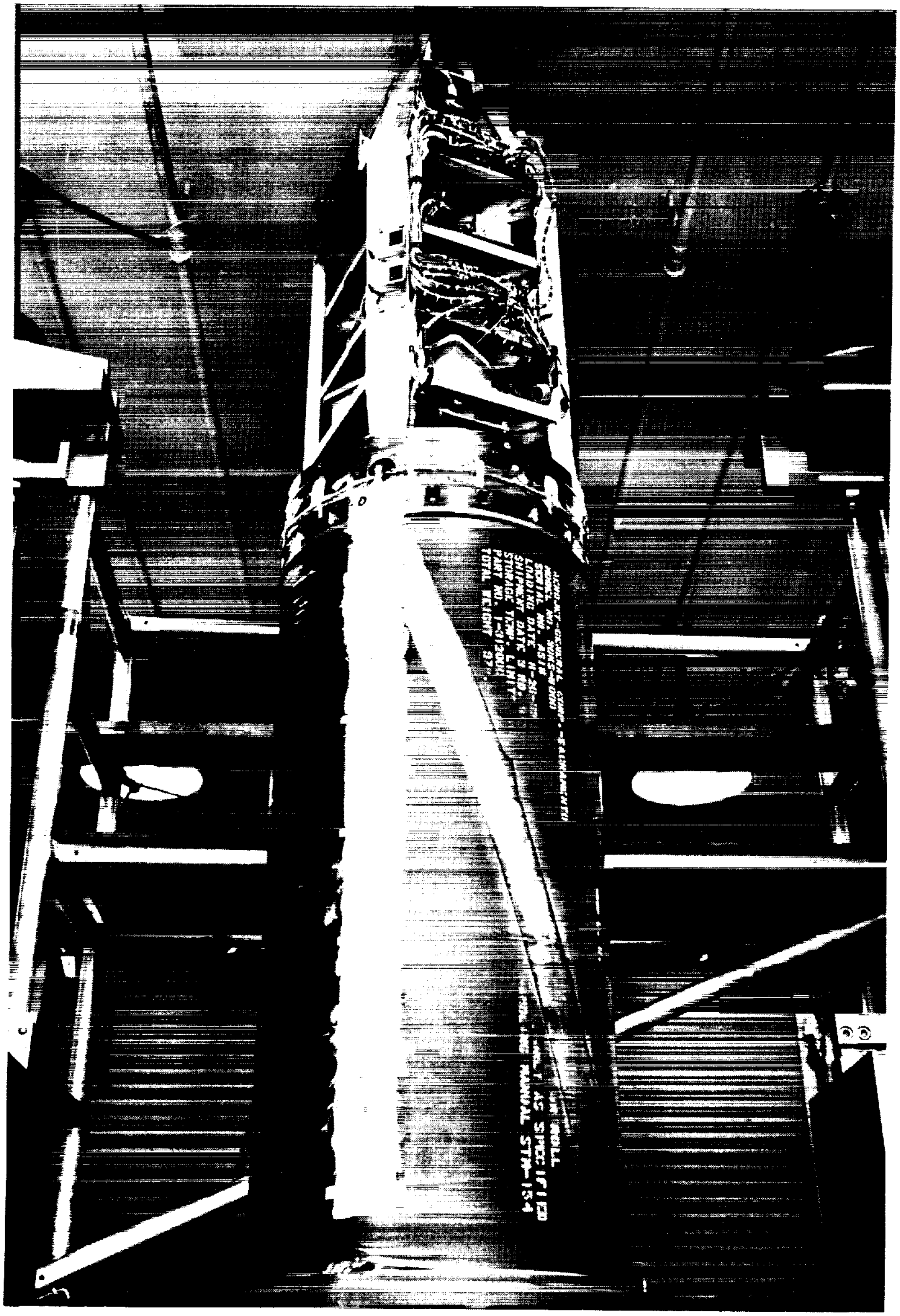


Figure 4. Payload on Dynamic Balance Test Stand

Table 2

FLIGHT 16.01 GENERAL INSTRUMENTATION

Telemetry System 1 (240.2 MHz)		
IRIG BAND	DATA	RANGE
18	Chamber Pressure (Stage I to Stage II switch at T+45)	0 to 1000 psig
17	Stage I Long. Vib. (Switch to solar aspect at T+45)	±20g
16	High Temperature Gages (Commutated)	0 to 1000° F
15	Longitudinal Acceleration	-10 to +60g
14	Low Temperature Gages (Commutated)	0 to 400° F
13	Acceleration (Aft pitch)	±10g
12	Acceleration (Aft yaw)	±10g
11	Voltage Monitors (Commutated)	
10	Event Monitors (Commutated)	
9	Roll (Gyro platform)	±360°
8	Pitch (Gyro platform)	±360°
7	Yaw (Gyro platform)	±85°
6	Roll (Magnetometer)	
5	Lateral Aspect (Magnetometer)	
Telemetry System 2 (231.4 MHz)		
E	Vibration (Longitudinal)	±40g
C	Vibration (Pitch)	±30g
A	Vibration (Yaw)	±30g

Table 2 (Continued)
FLIGHT 16.01 GENERAL INSTRUMENTATION

Telemetry System 2 (231.4 MHz) (Continued)		
IRIG BAND	DATA	RANGE
13	Acceleration (Forward pitch)	±10g
12	Acceleration (Forward yaw)	±30g
11	Acceleration (Longitudinal)	±30g
10	Strain (Payload support structure)	±5000 microinches/inch
9	Roll (Rate gyro)	±3600° /sec
8	Pitch (Rate gyro)	±2000° /sec
7	Yaw (Rate gyro)	±2000° /sec
6	Strain (Stage II motor skirt)	±5000 microinches/inch
5	Strain (Switched from spin table support to payload support housing at T+45)	±5000 microinches/inch
4	Strain (Switched from spin table support to payload support housing at T+45)	±5000 microinches/inch
3	Pressure (Payload compartment)	0 to 15 psia

16.01 FLIGHT ANALYSIS. Launch of Flight 16.01, originally scheduled for 15 January 1963, experienced a number of delays occasioned by vehicle sequencer unit and battery charging system modifications, RFI problems, and adverse weather. The vehicle was launched from Wallops Island at 1126Z hours on 8 April 1963. Ignition and liftoff appeared normal, and flight was as scheduled until T+16.5 seconds. At this time, telemetry became sporadic and partial breakup of the vehicle was observed. No indications of Stage II ignition were received and, after 148 seconds, all telemetry signals were lost. Radar plot board data indicated an apogee of 45 statute miles. Because of its impact in water, no portions of the vehicle were recoverable.

The apparent causes of flight failure were determined from the telemetry data received and from photographic coverage. An abrupt loss in Payload compartment pressure at 6.75 seconds was particularly significant, since this pressure then corresponded to that inside the heat shield. After viewing the motion pictures taken during that time, it was concluded that the clamshell heat shield had buckled from the large pressure differential at the attained velocity. This conclusion was later confirmed, by the vehicle manufacturer, when a clamshell placed in a test fixture failed in a similar manner, under simulated flight conditions.

Internal flow patterns within the Interstage, caused by the ruptured clamshell, resulted in premature firing of the explosive bolts and clamshell separation. The clamshells immediately broke off when opened at such a velocity. Resulting vehicle pitch and yaw movements caused Stage II separation, and final flight failure. This failure pattern, indicated by the telemetry received and by the film coverage, was substantiated by performance calculations and structural testing.

PROJECT RESPONSIBILITIES

Astrobee Flight 16.01 and Flight 16.02 carried the first GSFC-designed payloads devoted exclusively to instrumentation for measuring flight performance and environmental conditions. For this project, the combined efforts of the four sections within the Sounding Rocket Branch were required. General areas of responsibility of each of the four sections were as follows:

1. The Sounding Rocket Instrumentation Section was responsible for: design, fabrication, and testing the required telemetry systems; procurement of telemetry and instrumentation components and performance of qualification testing; the ascertaining of instrumentation and antenna space and arrangement requirements and advice on vehicle modifications necessary to facilitate installation; compilation calibration records and the collection of flight data; and the provision of playback records of performance data as required.

2. The Engineering Section was responsible for: design and fabrication of the payload racks, in accordance with Instrumentation Section requirements; reviewing of vehicle structural design, testing, and modifications; and assistance in launcher modifications.

3. The Flight Performance Section was responsible for: coordination with the Instrumentation Section in sensor and gauge selection; verification of vehicle stability and performance parameters; and for delegating and coordinating section project responsibilities.

4. The Vehicles Section was responsible for: preparation of the required range documentation, and providing a vehicle manager to work in conjunction with the project manager.

Upon determination of the cause of the vehicle failure of Flight 16.01, steps were taken to prepare the Flight 16.02 Payload. Concurrent with Payload preparation, the Astrobee 1500 configuration was modified to strengthen the nose fairing and the Interstage structure was redesigned. Table 3 gives a listing of the major steps involved in the payload preparation, and the programmed event dates.

Table 3
PROJECT SCHEDULING

DATE (1962)	EVENT
21 Mar	Performance instrumentation and telemetry system design completed.
27 Apr	Mechanical subsystem design completed.
2 May	Payload Control Console design completed.
6 Jun	Payload rack received.
26 Aug	Major payload components installation completed.
27 Aug	Transmitter checks.
2 Sept	Payload Control Console fabrication completed.
7 Sept	Conduct of payload balance and vibration tests.
15 Sept	Conduct of horizontal integration.
19 Sept	Vehicle delivered to Wallops Island.
3 Oct	Payload power checks completed.
4 Oct	Despin systems tested.
9 Oct	Vehicle assembly and horizontal checks
11 Oct	Vehicle installation on launcher.
12 Oct	Conduct of preflight vertical checks.
13 Oct	Flight 16.02 launch.

INSTRUMENTATION OF FLIGHT 16.02

While the basic Flight 16.02 instrumentation design (Figures 5 and 6) was similar to that of 16.01, various modifications and additional areas of coverage were incorporated on the basis of Flight 16.01 failure analysis. A third telemetry system and accompanying instrumentation was installed to monitor Stage I operation. Temperature transducers were relocated and their number increased. Major additional instrumentation included a clamshell position indicator, a three-axis vibration accelerometer, and a pitch-yaw ogive. Table 4 contains a complete listing of instrumentation flown on Flight 16.02, together with location and response data.

Table 4
FLIGHT 16.02 INSTRUMENTATION

LOCATION/REF.	MODEL NO.	RANGE
TEMPERATURE TRANSDUCERS		
T1 thru T3, T6 thru T8	Trans-Sonics T4100D	0 to 600° F
T4, T5, T11 thru T16, T18 thru T25	Trans-Sonics T4259BC	0 to 1000° F
T9, T10	Trans-Sonics T4097C	0 to 500° F
T17, T26 thru T34	Trans-Sonics T1375BN	0 to 600° F
STRAIN GAGES		
Stage I Motor Skirt (S1 thru S3)	BLH FA-37-12L	±5000 microinches/inch
P/L Support Ring (S4 thru S6)	BLH FA-37-12L	±5000 microinches/inch
SOLAR ASPECT SENSOR		
Stage II Extension	Adcole 135	±64°
Stage II Extension	OSU	

Table 4 (Continued)
FLIGHT 16.02 INSTRUMENTATION

LOCATION/REF.	MODEL NO.	RANGE
CLAMSHELL POSITION INDICATOR		
Clamshell Tip (Yaw)	Bourns 15620-17-2.50-502	5 inches
Clamshell Tip (Pitch)	Bourns 15620-17-2.50-103	5 inches
MAGNETIC ASPECT SENSORS		
P/L Deck 6 (Lateral)	Schonstedt Ram 5C	±600 milligause
P/L Deck 6 (Longitudinal)	Schonstedt Ram 5C	±600 milligause
OGIVE TRANSDUCER		
Clamshell Tip (Pitch/Yaw)	Gianinni 2519P	±7.5°
PRESSURE TRANSDUCERS		
Stage I Motor Dome (P_c 1)	CEC 4-326-0001	0 to 1000 psia
Stage II Motor Dome (P_c2)	CEC 4-326-0001	0 to 900 psia
Clamshell Pressure (P_c)	CEC 4-327-0003	0 to 18 psia
VIBRATION SENSORS		
P/L Support Ring (Vib. Thrust)	Endevco 2221D	±20g
P/L Support Ring (Vib. Pitch)	Endevco 2221D	±10g

Table 4 (Continued)
FLIGHT 16.02 INSTRUMENTATION

LOCATION/REF.	MODEL NO.	RANGE
P/L Support Ring (Vib. Yaw)	Endevco 2221D	±10g
Upper Clamshell (Vib. Yaw)	CEC 4-202-0001	±10g
Stage I Motor Dome (Low Yaw)	CEC 4-202-0001	±10g
Stage I Motor Dome (Low Thrust)	CEC 4-202-0001	-5 to +15g
ACCELEROMETERS		
P/L Deck 1 (3-axes: High Thrust, Lateral Pitch, and Lateral Yaw)	CEC 4-204-0001	+40g ±10g ±10g
P/L Deck 1 (Low Drag)	CEC 4-202-0001	±10g
STABLE PLATFORM		
P/L Deck 5 (Vehicle Aspect: Roll, Pitch, Yaw)	Whittaker 525145	Roll 360° Pitch 360° Yaw ±85°

TEMPERATURE TRANSDUCERS

A total of 34 temperature transducers (T1 through T34), shown in Figure 5, were utilized to measure various temperatures associated with vehicle performance and payload environment. Transducers T9 and T10 were used to measure air temperature, and all others to measure surface temperatures (see Figure 7 for typical examples).

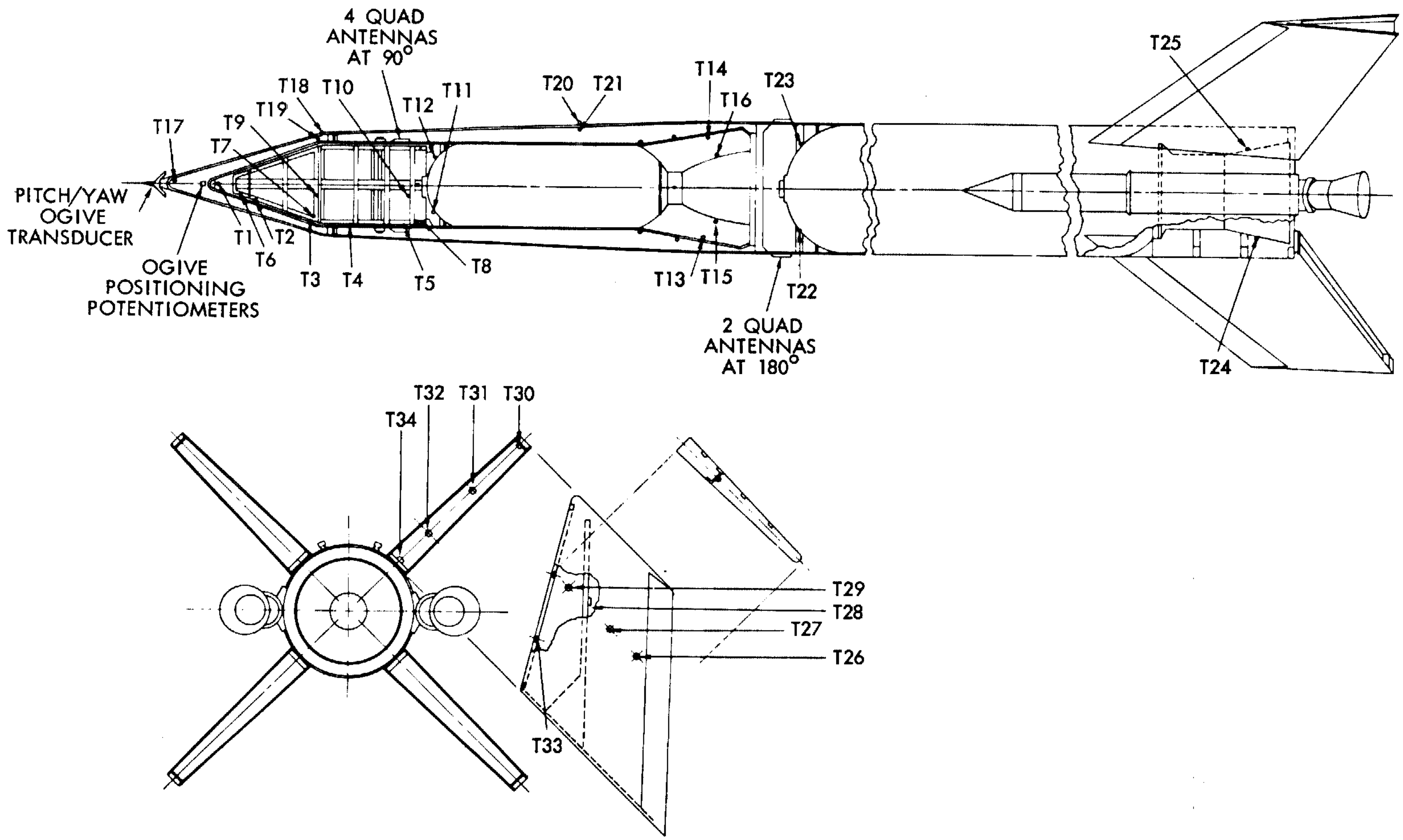
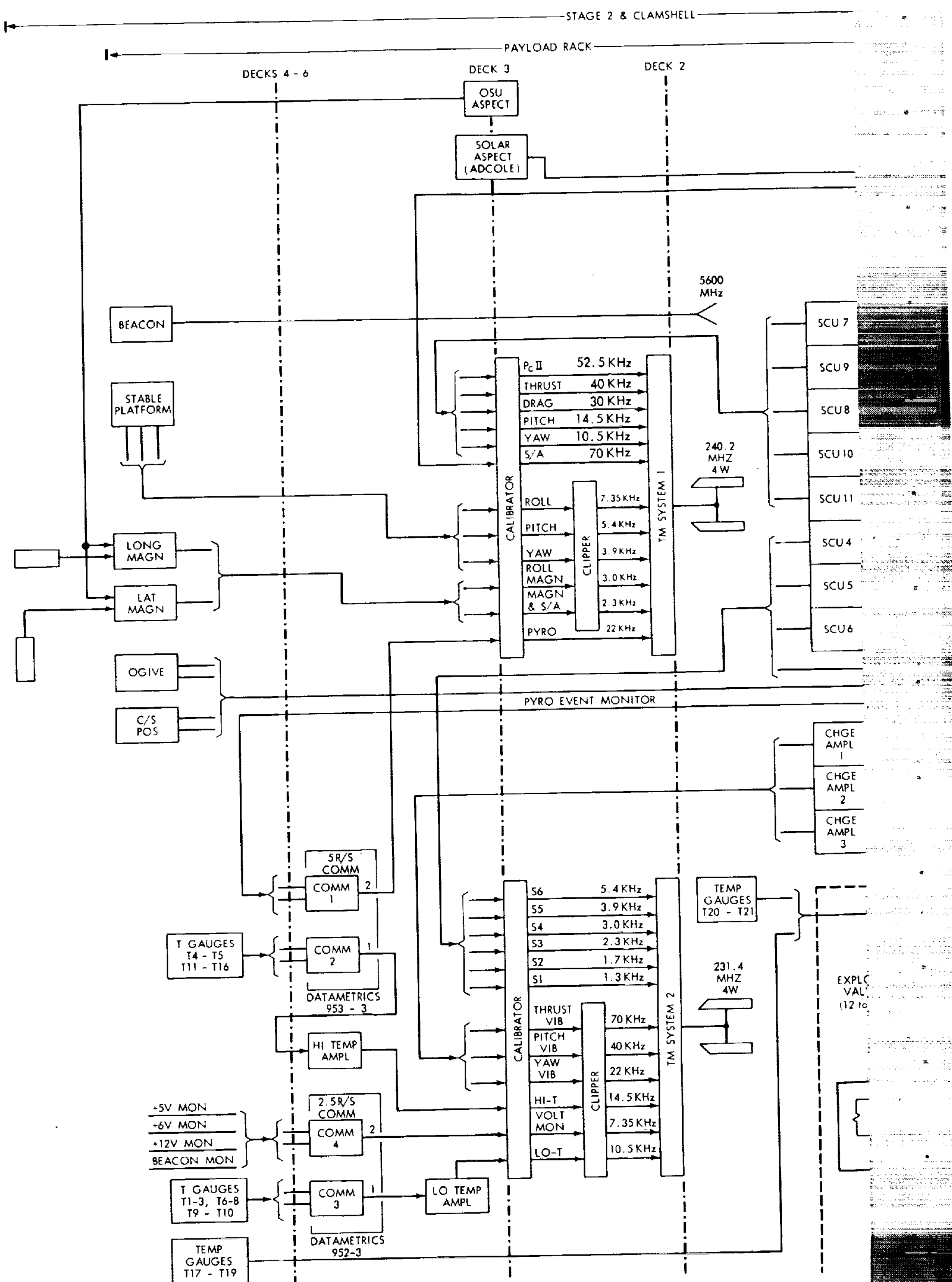


Figure 5. Instrumentation of Flight 16.02, Temperature Gauge Locations



FOLDOUT FRAME 1

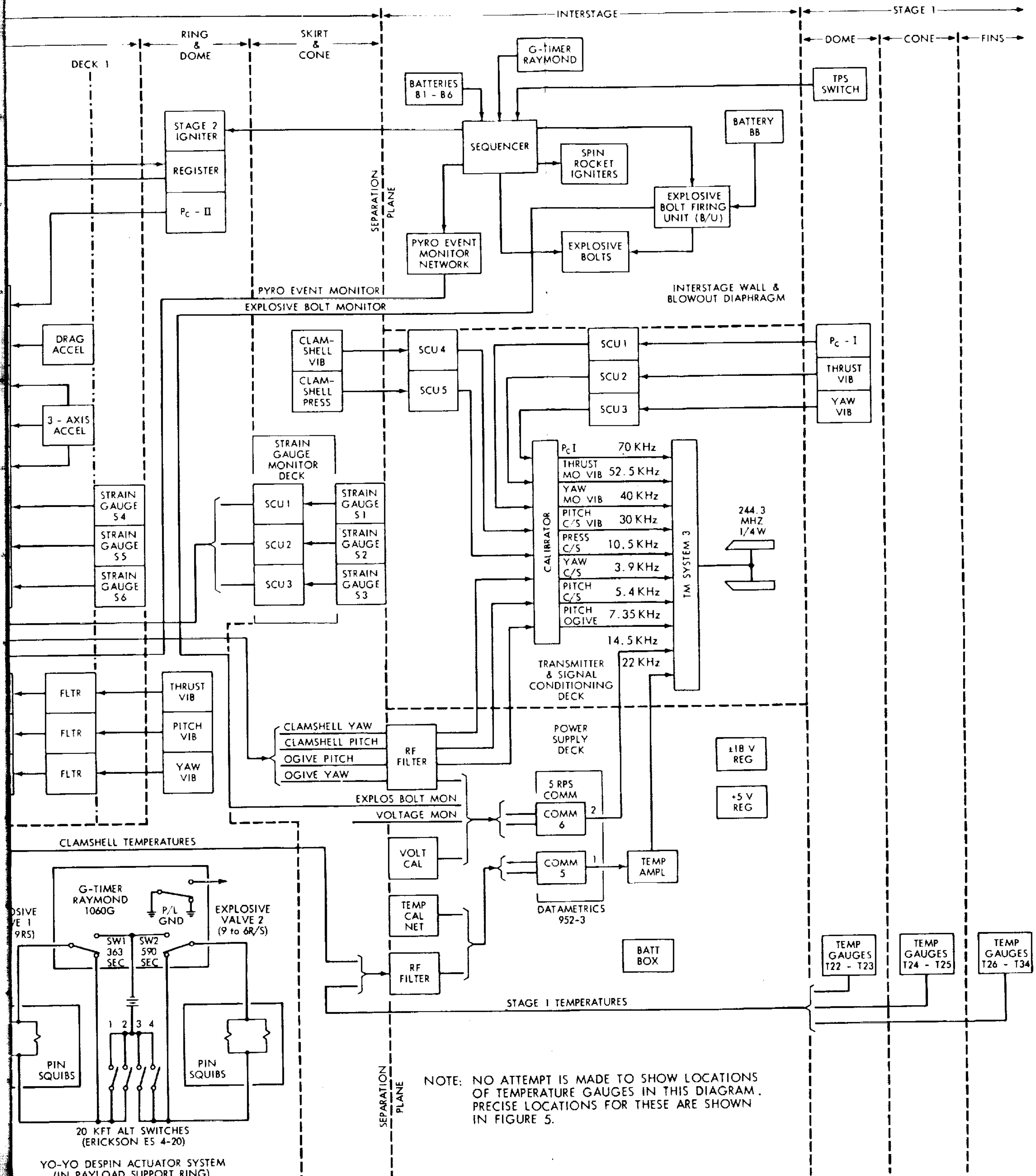


Figure 6. Instrumentation of Flight 16.02

FOLDOUT FRAME 2

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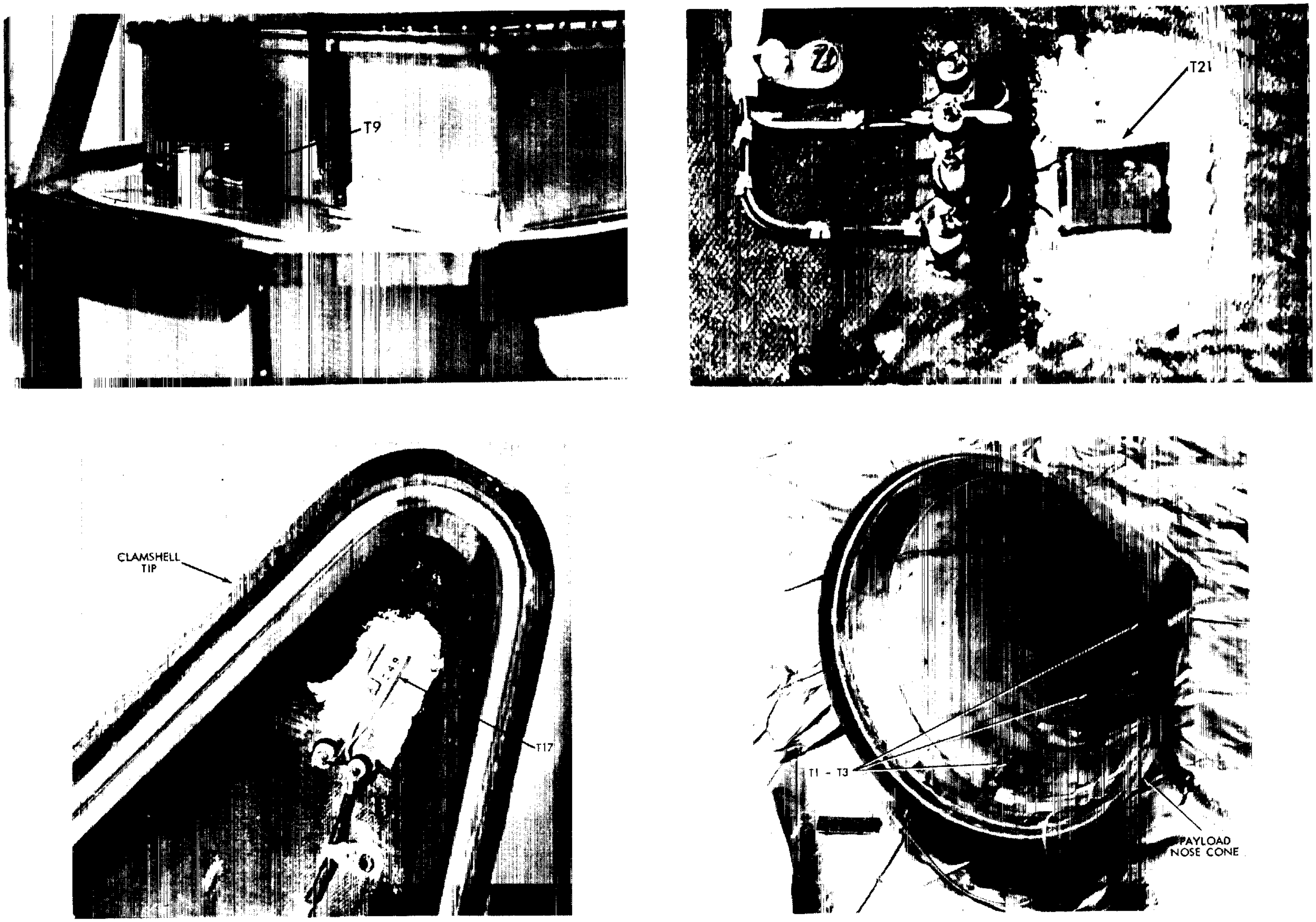


Figure 7. Temperature Transducer Installations (typical)

Air temperature gauges T9 and T10 were open-type resistance thermometers located on the payload first and fourth decks. Each gauge consisted of a platinum wire sensing element, wound on four posts contained in a cylindrical probe. The probe was open at one end to provide a gas inlet, and was vented to produce a free flow over the sensing element. Through an operating range of 0 to 500 degrees F, element resistance varied from 527 ohms ±0.5 percent at 0 degrees F to 1203.6 ohms ±0.75 percent at full scale. Weight of the unit was less than 2 ounces and probe length was one inch.

Surface temperatures were measured with Trans-Sonics Models T4100D, T4259BC, and T1375BN temperature transducers. Operating range of the first was 0 to 600 degrees F while the others were calibrated for operation between 0 to 1000 degrees F. Except for T17, which was installed in the clamshell tip, all Model T1375BN gauges were bonded to the inner surfaces of the tail fin to prevent spurious readings from radiation or air convections.

All gauges employed either platinum or nickel resistance windings encased in a stainless steel envelope with nickel leads. Representative calibration curves of the various gauges are contained in Appendix A.

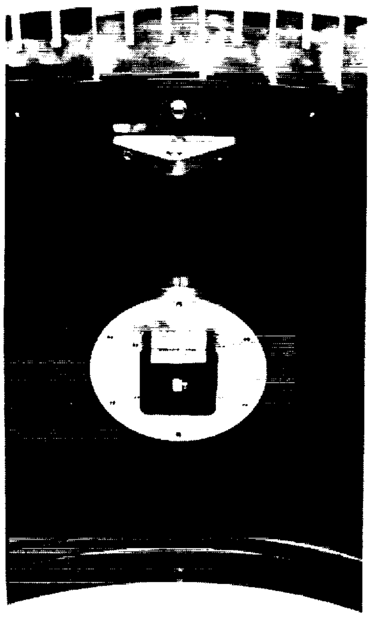
STRAIN GAUGES

Strain gauges S1 through S3 were mounted 120 degrees apart on the Stage II aft skirt; S4 through S6 were mounted on the Payload legs (Figure 8). Each gauge was of the constantan foil type, with an epoxy base backing and had a nominal resistance of 120 ohms. The gauge factor was 2.1, and overall size was 0.75 inch by 0.50 inch. The gauges were primarily installed to provide useful information between yield and ultimate strain levels, in the event of complete vehicle failure. Sample strain gauge calibration curves are supplied in Appendix A.

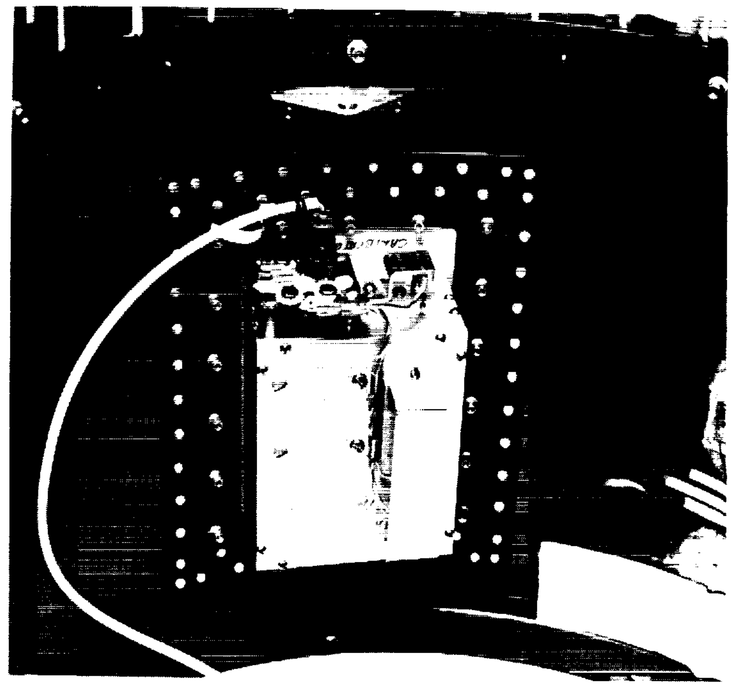
SOLAR ASPECT SENSORS

An Adcole Model 135 solar-aspect sensor (see Figure 9) and shift-register system was employed to assist in the determination of vehicle attitude, by producing a digital measurement of the angle of incident sunlight with respect to the vehicle coordinate axis. Aspect data from the Adcole sensor was supplemented by data from an Oklahoma State University (OSU) designed sensor (Figure 9). The Adcole sensor consists of both Gray coded and command reticles, with photocells for sun sensing and a photocell and telescope for sensing the earth. Signal conditioning and programming circuitry was contained in the shift register, located on the despin unit and payload mount.

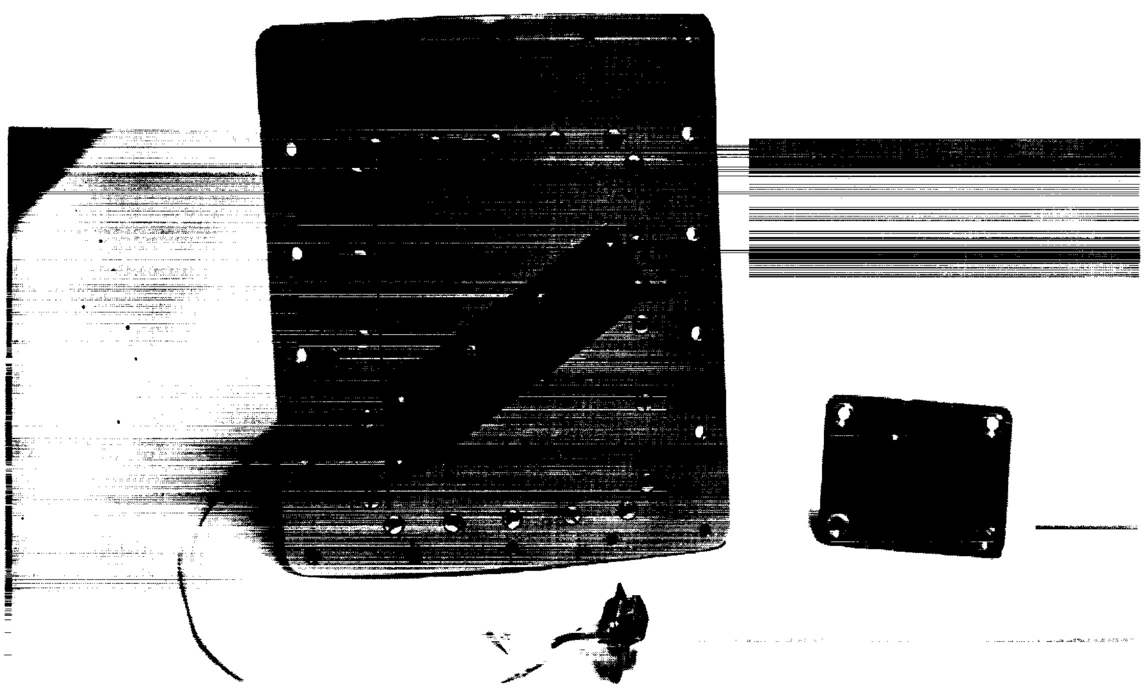
Figure 8. Strain Gauge Installations



Adcole Sensor Installed



OSC Sensor Installed



Front View of Sensors

Figure 9. Solar Aspect Sensors

The sensor was so mounted on the forward payload extension that the Gray coded reticle was parallel to the rocket lateral plane, the command reticle parallel to the longitudinal axis, and the earth telescope pointing aft. Sunlight passing through the Gray coded reticle slit is screened by a Gray coded pattern to alternately illuminate each of seven photocells, depending upon the angle of incidence. This provides 128 combinations of "zeros" and "ones" which represent a coverage of 128 degrees in one-degree increments. Photocell outputs are amplified and stored in the shift register.

Two slits, located 90 degrees from a photocell, serve as the sensor trigger by permitting angle readout only when the sun is in a plane at right angles to the Gray coded reticle. This occurs once every revolution of the spinning rocket. The earth telescope, tilted aft at a 10 degree angle, with respect to the rocket lateral axis, illuminates a photocell when the earth is in view to determine the reference level of the Gray coded word at the shift register output.

When the shift register is triggered by the command reticle, an eight-bit telemetered word consisting of "zeros" and "ones", and having a 50 percent duty cycle, is produced (refer to the solar aspect data in Appendix A). The most significant (M.S.) bit indicates whether the sun is at a plus or a minus angle, with respect to the rocket lateral axis. The next six bits determine the sun angle of incidence in a 64-degree range, and the end word bit is for reference to indicate sensor type.

Weight of the Adcole sensor is 4 ounces and that of the shift register is 15.5 ounces. The earth telescope has a 1 degree ±0.25 degree conical field of view, and the solar sensor has an angular resolution of 1 degree, with a field of view of ±64 degrees.

Sensor accuracy was checked with the SRIS-designed test fixture shown in Figure 10. The sensor was mounted and oriented so that a pin shadow was centered on the horizontal scale, and on -10 degrees (for positive sweep) on the vertical scale. Using a synchronous motor, the sensor was rotated to +70 degrees on the vertical scale. Timing circuitry contained in the fixture synchronized the motor speed so that angular displacement from the -10 degree position could be recorded on one channel of the recorder, while the second channel recorded aspect data from the shift register. A comparison of the two channels indicated that data was accurate to within ±1 degree. The check was then repeated by a negative sweep, with the pin shadow on +10 degrees, and the sensor rotated to -70 degrees.

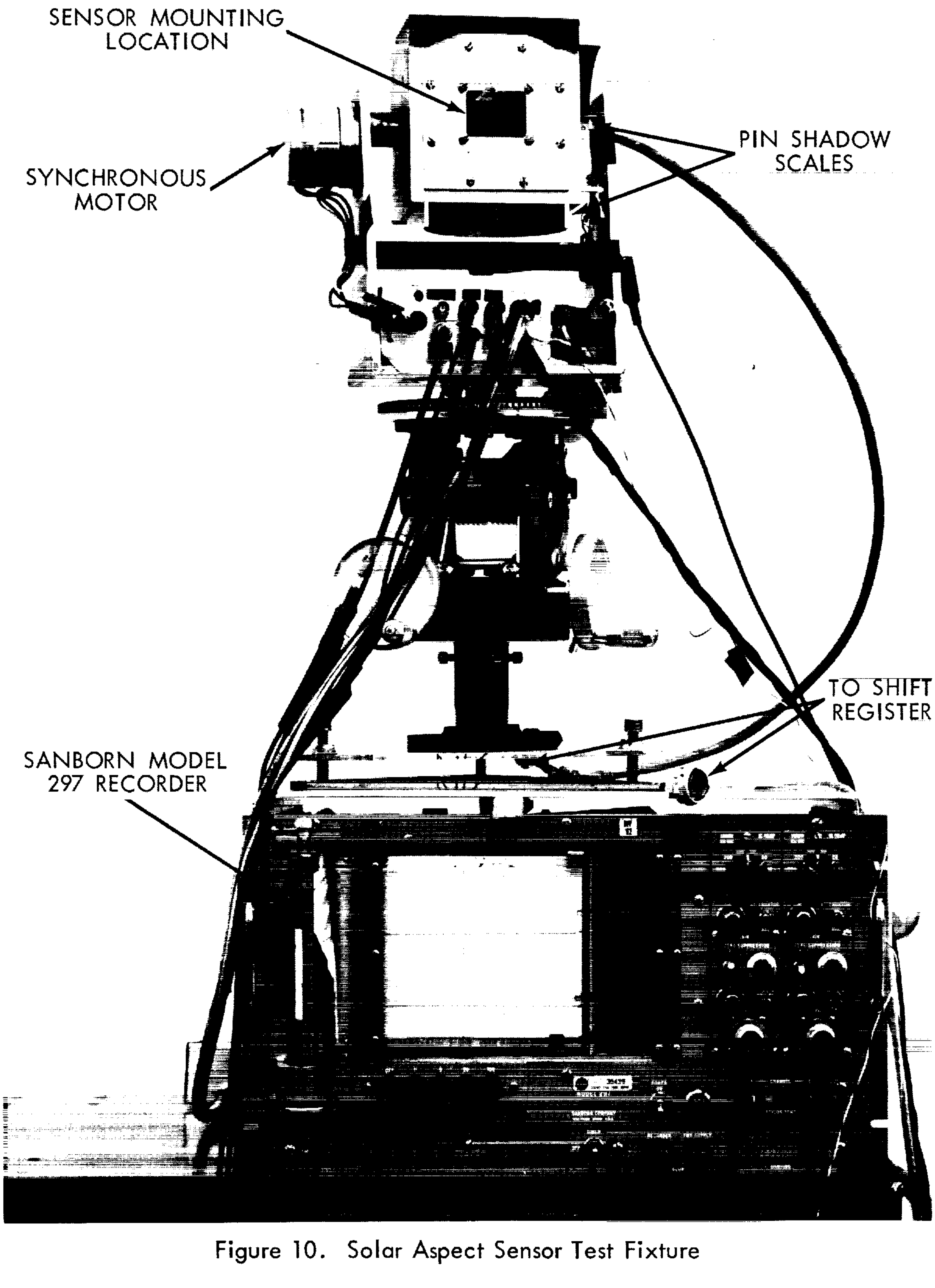


Figure 10. Solar Aspect Sensor Test Fixture

CLAMSHELL POSITION INDICATOR

The clamshell position indicator (Figure 11) consisted of two spring loaded position probes, mounted near the clamshell tip, so that the tip of each probe bore against the clamshell side. Each of the two rigid position probes was attached to the arm of a linear motion potentiometer. A rod projecting from the payload nose-cone automatically centered the assembly. During the flight, any pitch or yaw movement of the clamshell, relative to the second stage, would move the probe and actuate its associated potentiometer.

MAGNETIC ASPECT SENSORS

Two magnetic aspect sensors were used to measure the strength and direction of the earth's magnetic field with respect to the rocket lateral and longitudinal axis. Each sensor (Figure 12), which consisted of a permalloy core surrounded by two windings, was connected to an electronic unit containing a phase sensitive rectifier regulated by a +2.4-volts dc bias source and a regulated oscillator. As the regulated oscillator generates a 500-Hz excitation current through one of the sensor windings, a magnetic field, sufficient to drive the core into saturation, is generated. The presence of an external field parallel to the sensor axis will induce a voltage, whose frequency is the second harmonic of the excitation frequency, into the second winding. This voltage is then converted into a dc signal by the rectifier.

Since the rectifier output is biased by +2.4 volts dc, the sensor output varies over a range of 0 to +4.8 volts dc. Each sensor has a range of +600 to -600 millioersteds, and thus will produce outputs of +2.4 to +4.8 volts dc, and of +2.4 to 0 volts dc, respectively. Sensitivity of each sensor was 0.0004 volts dc per millioersted, which is ±3 percent of full scale linearity. Both sensors were mounted in phenolic holders to minimize interaction with the surrounding metal structure. Representative calibration curves are shown in Appendix A. Final flight data, used in conjunction with a trajectory (altitude vs time) radar plot, and a magnetic sounding (field strength versus altitude) for the launch site, were used to determine vehicle attitude and dynamic motion.

OGIVE TRANSDUCER

Information concerning angle of attack in relation to vehicle pitch and yaw was obtained from an ogive transducer located at the tip of the clamshell (Figure 10). The ogive transducer consists of an ogival-shaped shell with four vane-type fins which swivel with respect to a stationary boom mounted in line with the vehicle longitudinal axis. Two potentiometers, mounted within the shell,

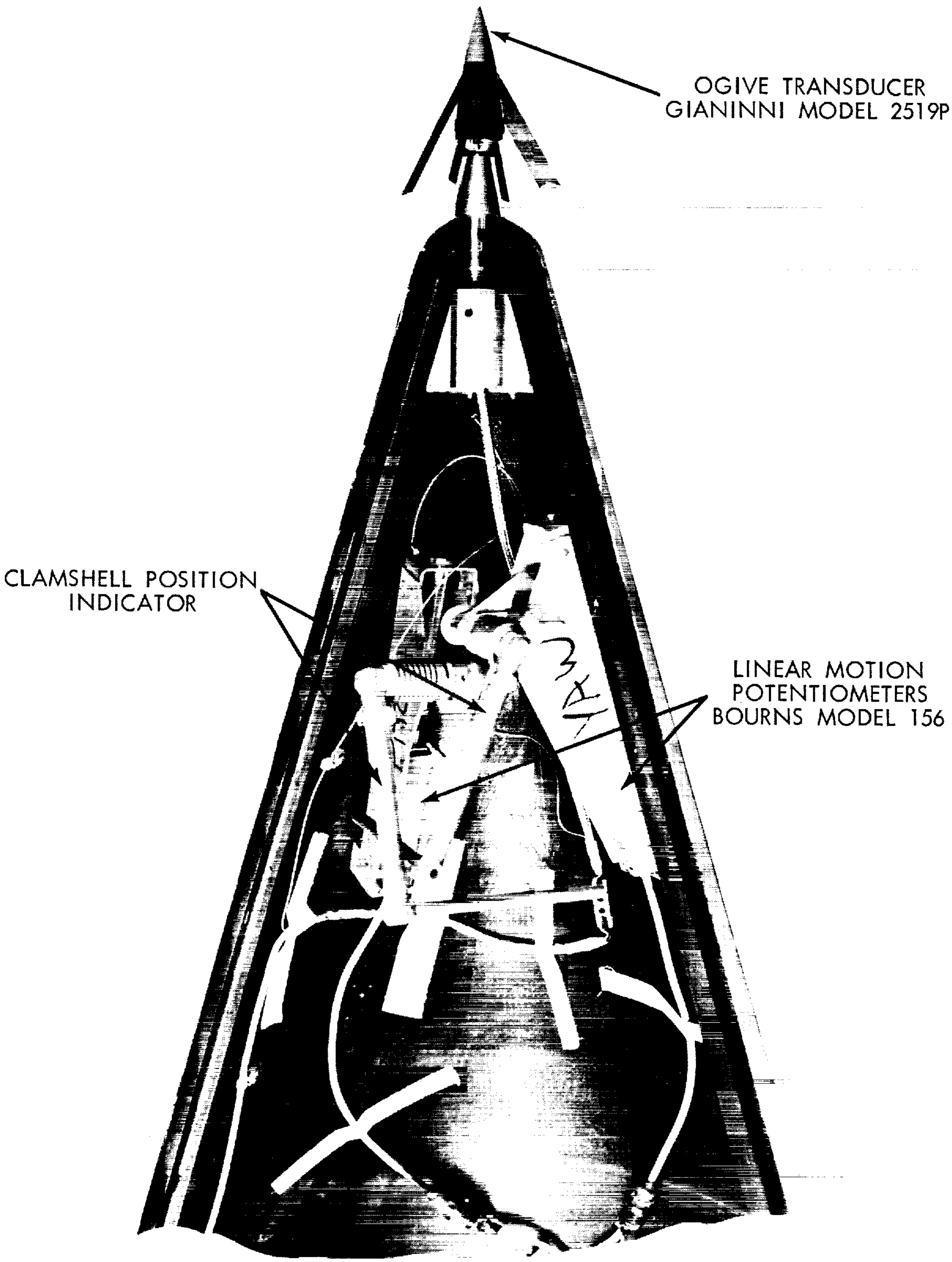


Figure 11. Clamshell Position Indicator and Ogive Unit

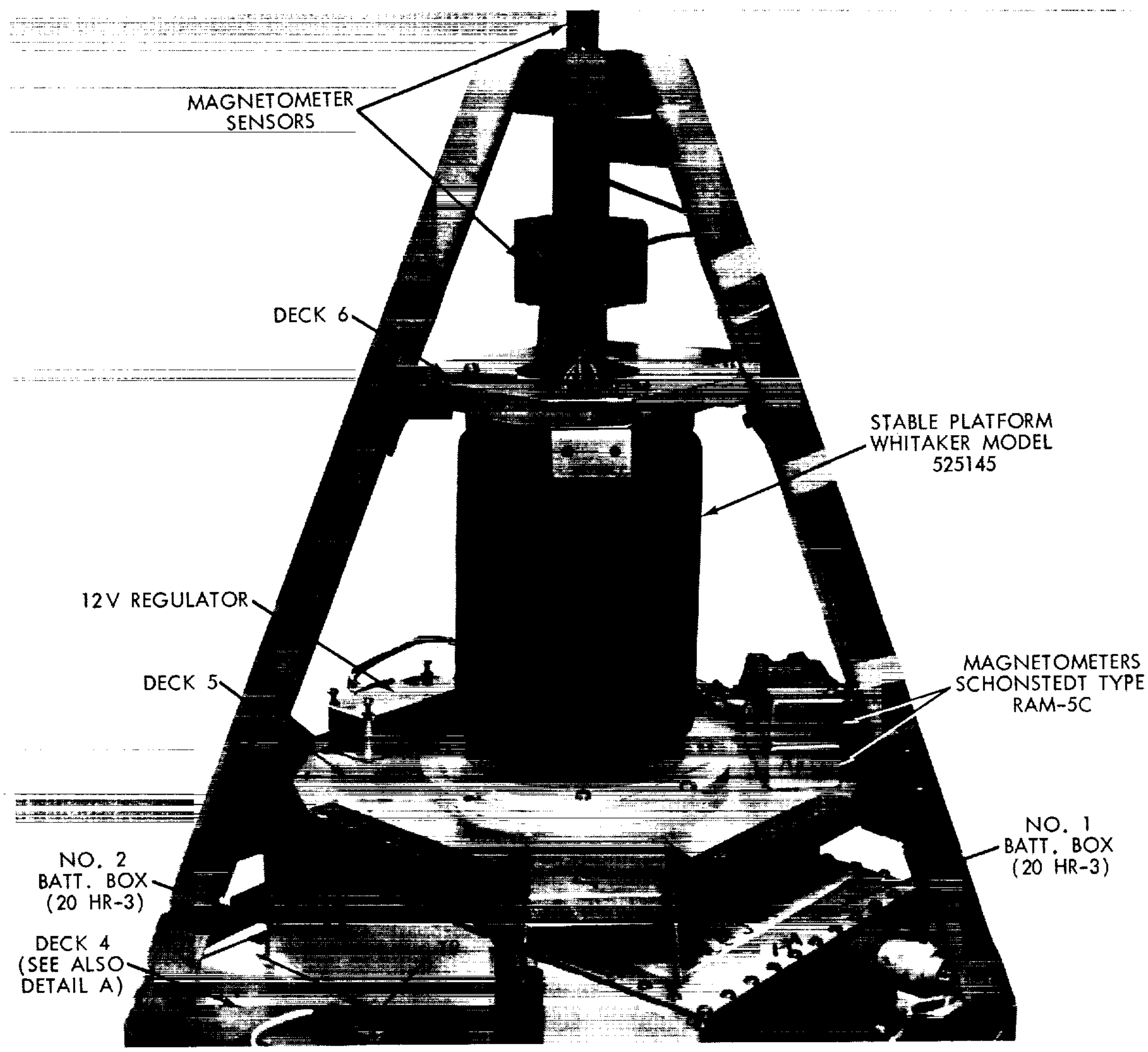


Figure 12. Component Installations on Decks 4, 5, and 6

indicate angles of pitch or yaw in response to the action of the vanes. Mechanical stops limit the maximum angular displacement in either direction to ±7.5 degrees.

A 5-volts dc regulated voltage is placed across the potentiometers, which are adjusted so that when the pitch and yaw angles are zero a +2.5-volt dc reference level is produced. In flight, the shell aligns itself with the wind stream. This actuates the potentiometers which produce a voltage corresponding to angles of pitch and yaw. Transducer resolution was such that a ±0.2 degree variation would produce a change in output. Calibration curves for the ogive transducer are included in Appendix A. Unit weight, less regulator and interconnecting leads, was 6.4 ounces.

STABLE PLATFORM

The primary source of information concerning vehicle aspect was a roll-stabilized (gyro) platform Whittaker Model 525145 MARS (Miniature Attitude Reference System) used to determine pitch, yaw, and roll. The platform was referenced to the initial launch position and isolated from vehicle spin. This platform, located on the payload fifth deck (Figure 12), consists essentially of inner and outer gimbals mounted to sense roll and yaw, while a third gimbal measures pitch. The gyros, driven by induction type motors, are mounted to a common frame which is isolated from longitudinal rotation by a d-c servo loop. Caging is done by means of a caging motor, and control circuitry which locks the gimbals, to establish initial reference for the system.

The yaw gyro has a three-segment potentiometer, the pitch gyro has an eight-segment potentiometer, and the roll gyro has a four-segment potentiometer. The yaw, pitch, and roll segments measure 60 degrees, 45 degrees, and 90 degrees, respectively, with a resolution of 0.5 percent. Each segment is so biased by a regulated 5 volts dc that a nominal 2.5 volts dc reference level is established regardless of initial platform position. When uncaged, the reference output will remain at 2.5 volts dc until deviations of vehicle attitude cause changes in the output levels. As soon as each output reaches a nominal +5 volts dc level, it switches almost instantaneously to a 0 volt dc level. Operational freedom of the yaw, pitch, and roll gyros are ±85 degrees, 360 degrees, and 360 degrees, respectively.

Performance of the stable platform was tested prior to flight by mounting it upon the turntable as shown in Figure 13. After a 15-minute warmup period, caged and uncaged output reference levels were recorded and compared. Calibration voltages, in 1-volt steps from 0 to +5 volts dc, were then recorded from

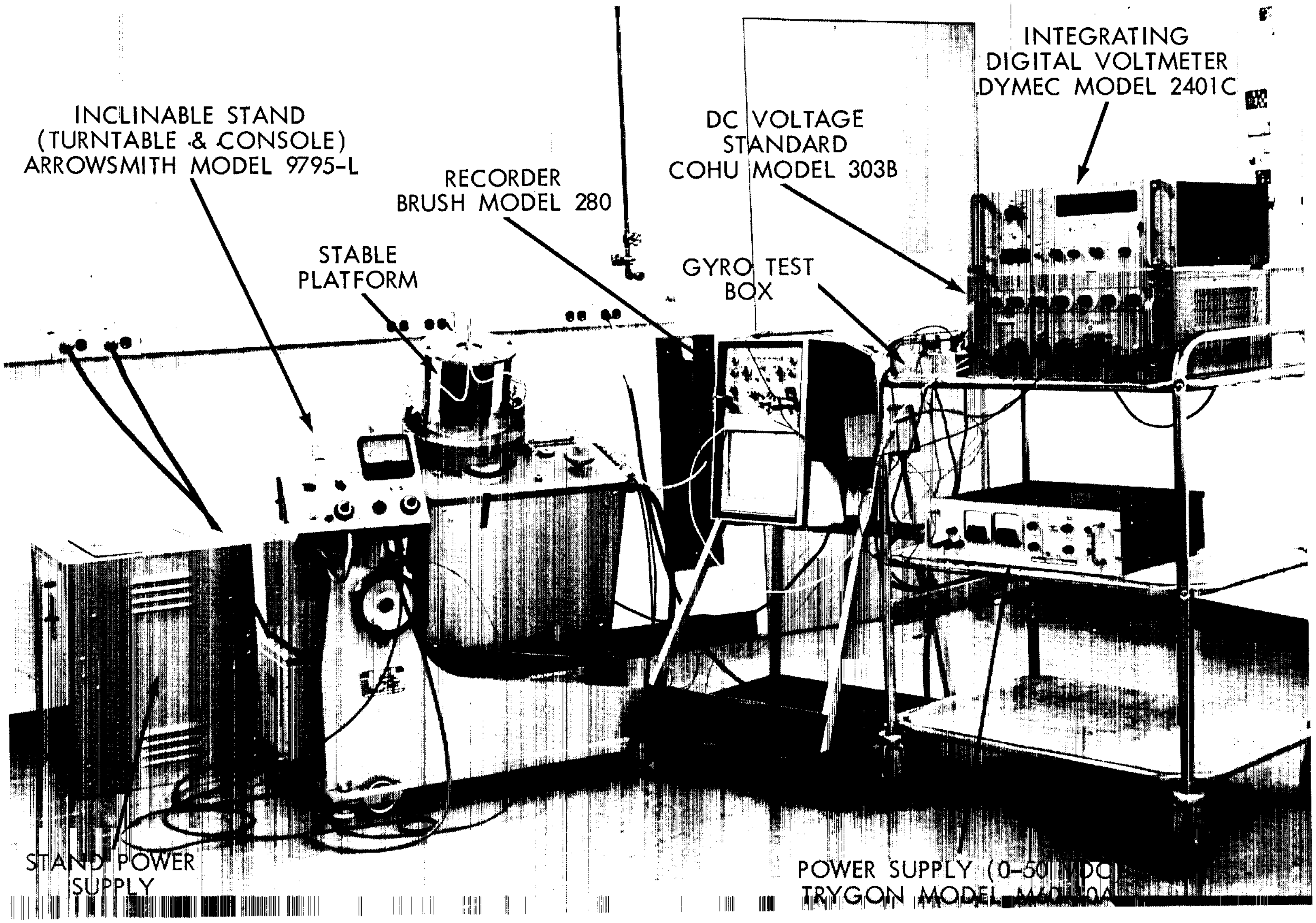


Figure 13. Stable Platform Test Set-up

the voltage standard and compared with recorded output voltages for each gyro at various angles of inclination. Data derived agreed with that supplied by the manufacturer.

PRESSURE TRANSDUCERS

Stage I and Stage II motor pressures were continuously monitored by 0 to 1000 and 0 to 900 pounds per square inch pressure transducers installed in each motor dome. In addition, interior clamshell pressure was monitored by a 0 to 18 pounds per square inch transducer (Figure 14).

Each transducer consists of a force summing diaphragm, attached to a spring-type sensing element, with four active arms of Wheatstone bridge design. Applied pressure causes displacement of the diaphragm, which changes the resistance of the active arms. A 5-volts dc excitation voltage, applied across two junctions of the bridge, then produces an output across the remaining two junctions which is directly proportional to the applied pressure, or 0 to +20 millivolts for pressures of zero pounds per square inch to the maximum rated value of the gauge. The output is expanded to the nominal telemetry input range of 0 to 5 volts dc by a BLH Model 950 signal conditioning unit, which also supplies the excitation voltage.

Tests were performed to ensure proper transducer operation and adherence to specifications. All tests were conducted with the gauges matched with their associated signal conditioning units. Each transducer was placed in a bell jar and the pressure lowered to zero pounds per square inch. The output voltages were checked for residual unbalance. Linearity tests were then performed, and calibration data were recorded, with the transducer attached to an air pressure tester. Appendix A contains sample calibration curves for pressure transducers.

ACCELEROMETERS

Two accelerometers, one being triaxial, were mounted on the Payload first deck (Figure 15). One module of the three axis unit was used to measure high level thrust along the longitudinal axis while the other two modules detected lateral pitch and yaw motions. The single module unit was used to measure low level (drag) longitudinal acceleration. Excitation voltage for each accelerometer was supplied by individual BLH Model 950 signal conditioning units.

Each module consists of four strain-sensitive unbonded gauge elements, comprising a Wheatstone bridge configuration. The sealed unit contains a

NASA W-64-586 Figure 14. Pressure Transducer Installations

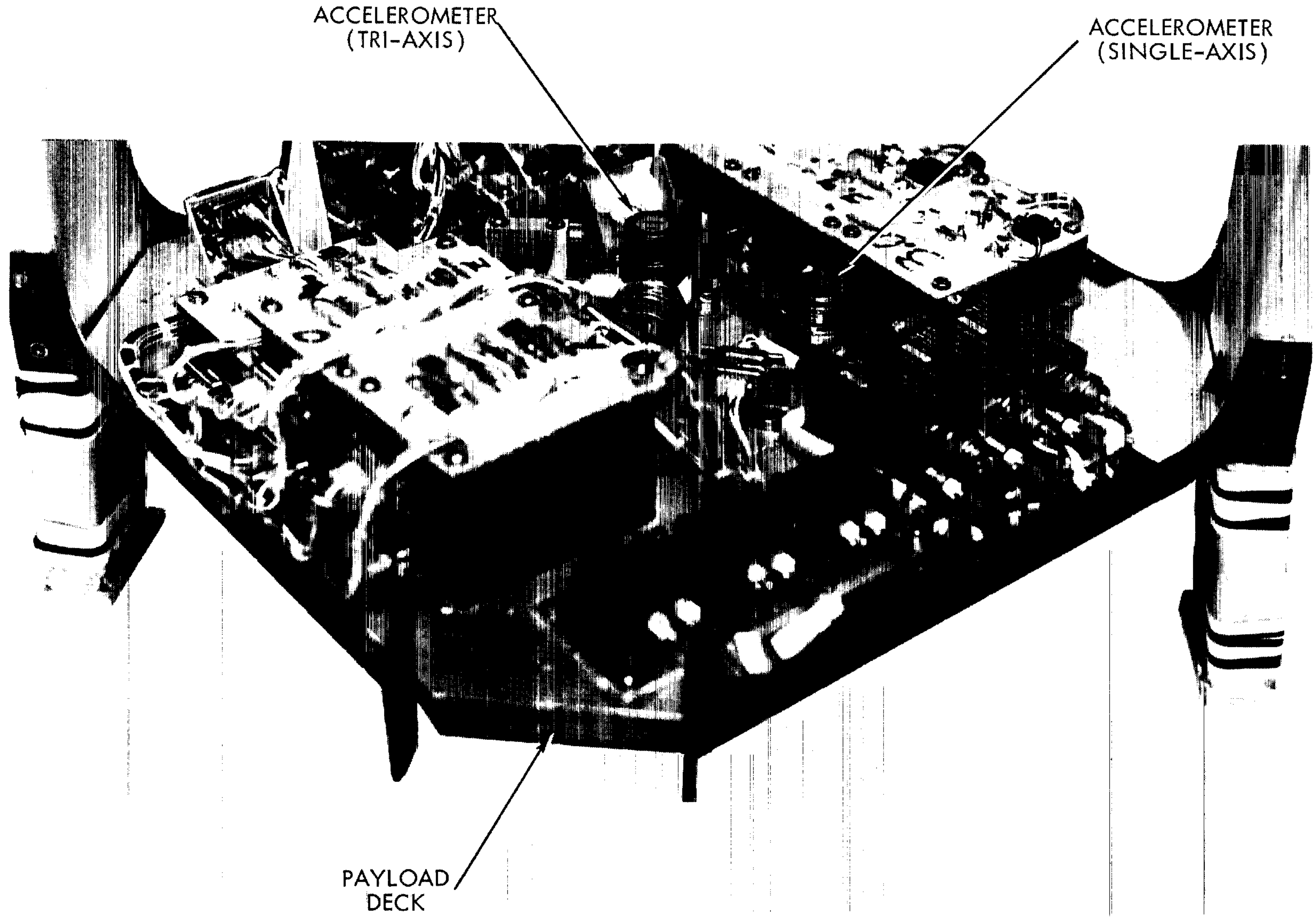


Figure 15. Accelerometer Installations

seismic mass, and damping viscuous fluid. When force is applied to the elements by the mass, the bridge becomes unbalanced, producing an output of about 40 millivolts (at full range) which is applied to the signal conditioning unit (SCU).

Appendix A contains accelerometer calibration curves. Mounted on a spin table, each accelerometer was rotated at various speeds, and the output voltages from the associated SCU were recorded.

VIBRATION SENSORS

Three Endevco Model 2221D vibration pickups were mounted on the Payload support ring (Figure 16) to measure thrust, pitch, and yaw vibrations. The sensors were of the piezoelectric self-generating type, with nominal outputs of 13 peak millivolts per peak g. Installation was by insulated mounting screws to ensure electrical and mechanical isolation. Weight of each unit, including mounting screw, was 0.43 ounce.

Amplification of each accelerometer output was by an Endevco Model 2646M1 charge amplifier, consisting essentially of a charge converter which supplies an output voltage proportional to the transducer charge, and an amplifier to raise the voltage to a 5-volt dc level suitable for telemetry. The charge amplifier offers two main advantages over conventional amplifiers. It directly monitors the accelerometer output so that low frequency transfer characteristics are eliminated; and, the length of interconnecting cable does not appreciably attenuate the charge signal.

Payload thrust, pitch, and yaw vibrations were telemetered on wide band channels to ensure wide frequency response without distortion. Static and dynamic low-frequency accelerations in the areas of the upper clamshell and Stage I motor dome were measured with CEC Model 4-202-0001 strain gauge accelerometers. The operation of these units was as previously described.

PAYLOAD ASSEMBLY

The Flight 16.02 payload consisted of an Interstage telemetry system, two Stage II telemetry systems, and associated instrumentation. Total net payload weight, exclusive of nose cone and extensions, was 138 pounds.

STAGE II TELEMETRY SYSTEMS

The major portion of Stage II payload components were secured to a 6-shelf rack, located in the payload compartment, at the forward end of the

Figure 16. Vibration Accelerometer Installations

State II motor. This compartment normally provides about 6.1 cubic feet of useable volume. Figures 17, 18, 19 and 20 illustrate Flight 16.02 Stage II payload and component installations, except for the ogive and certain temperature sensors which were located elsewhere on the vehicle. Note that the strain gauge signal conditioning circuits (Figure 20) were located inside the Stage II skirt.

The Stage II payload incorporated two telemetry systems (Figures 21 and 22), each employing a 4-watt FM/FM telemetry transmitter (Dorsett Model TR-20-A). The transmitters, which were modulated by 12 voltage-controlled oscillators (VCO), transmitted flight performance and payload environment data. The carrier frequency of transmitter 1 was 240.2 megahertz; that of transmitter 2 was 231.4 megahertz, each with a deviation of ±125 kilohertz. Table 5 lists the data allocations and associated IRIG bands of Telemetry System 1.

Table 5
TELEMETRY SYSTEM 1, VCO IRIG BAND PARAMETERS

FREQUENCY (KHz)	IRIG BAND	ALLOCATION
70.0	18	Solar Aspect
52.5	17	Chamber Pressure, 0 to 900 psi
40.0	16	High Thrust, +40g
30.0	15	Low Drag, ±10g
22.0	14	Event Monitors, Commutated
14.5	13	Lateral Pitch, Acceleration ±10g
10.5	12	Lateral Yaw, Acceleration ±10g
7.35	11	Stable Platform, Roll 360°
5.4	10	Stable Platform, Pitch 360°
3.9	9	Stable Platform, Yaw ±85°
3.0	8	Magnetometer, Roll
2.3	7	Magnetometer Thrust & Solar Aspect

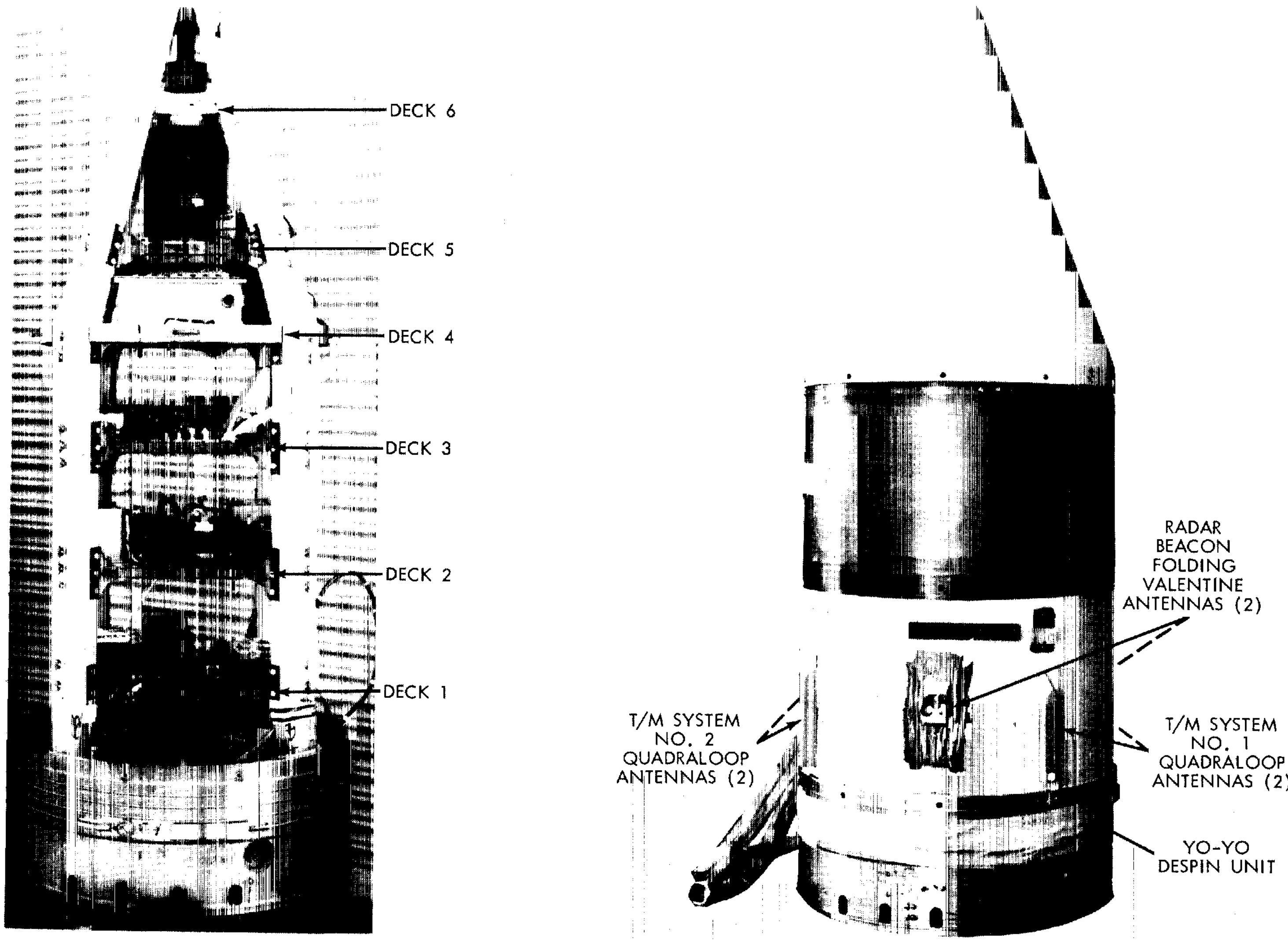
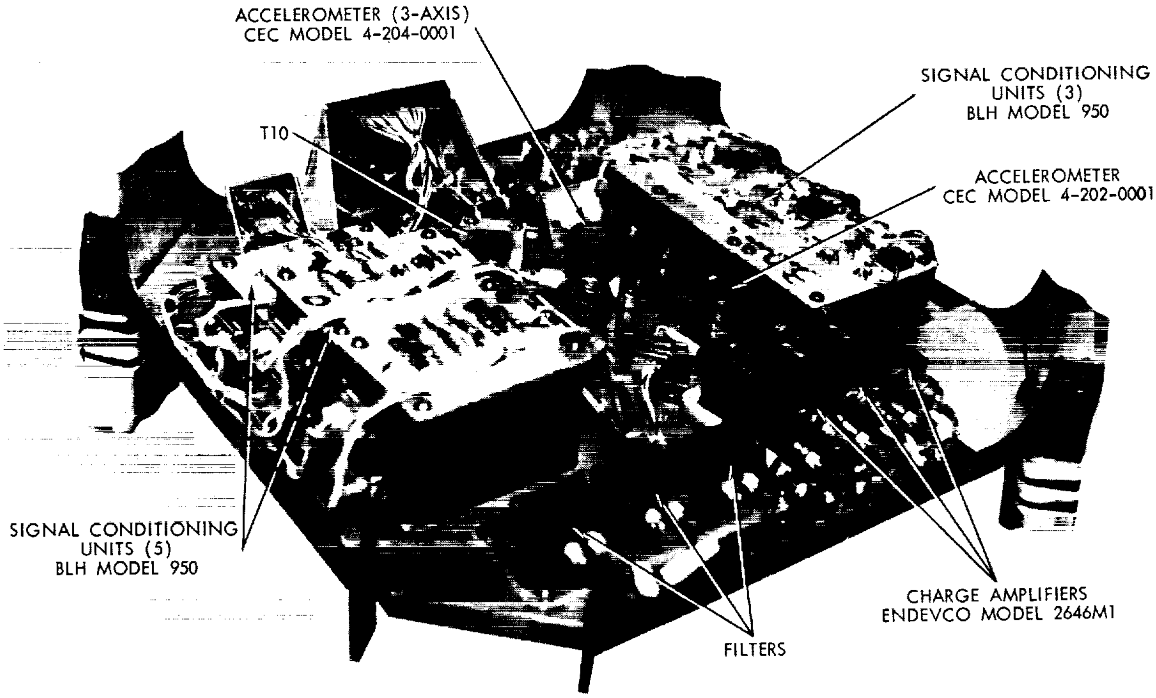


Figure 17. Stage II Payload



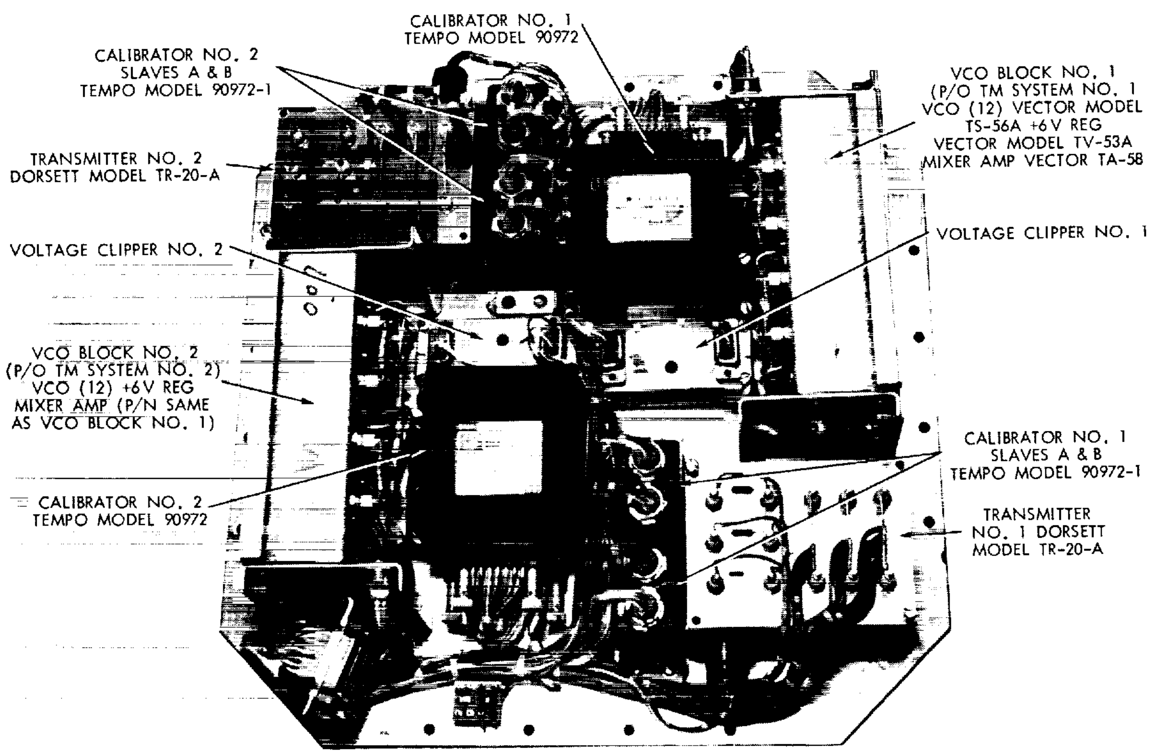


Figure 18. Stage II Payload Component Installations on Decks 1 and 2

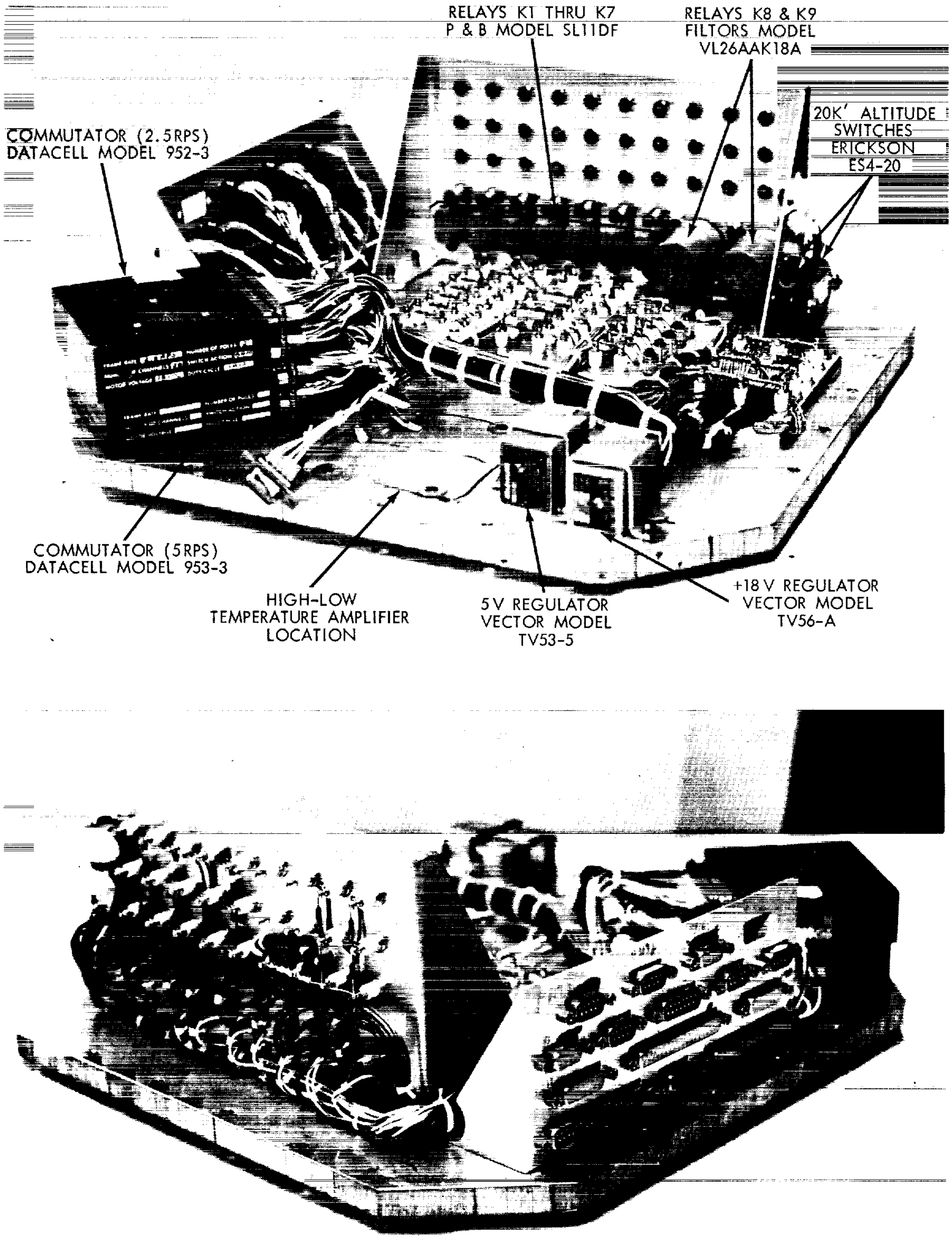


Figure 19. Stage II Payload Component Installations on Deck 3

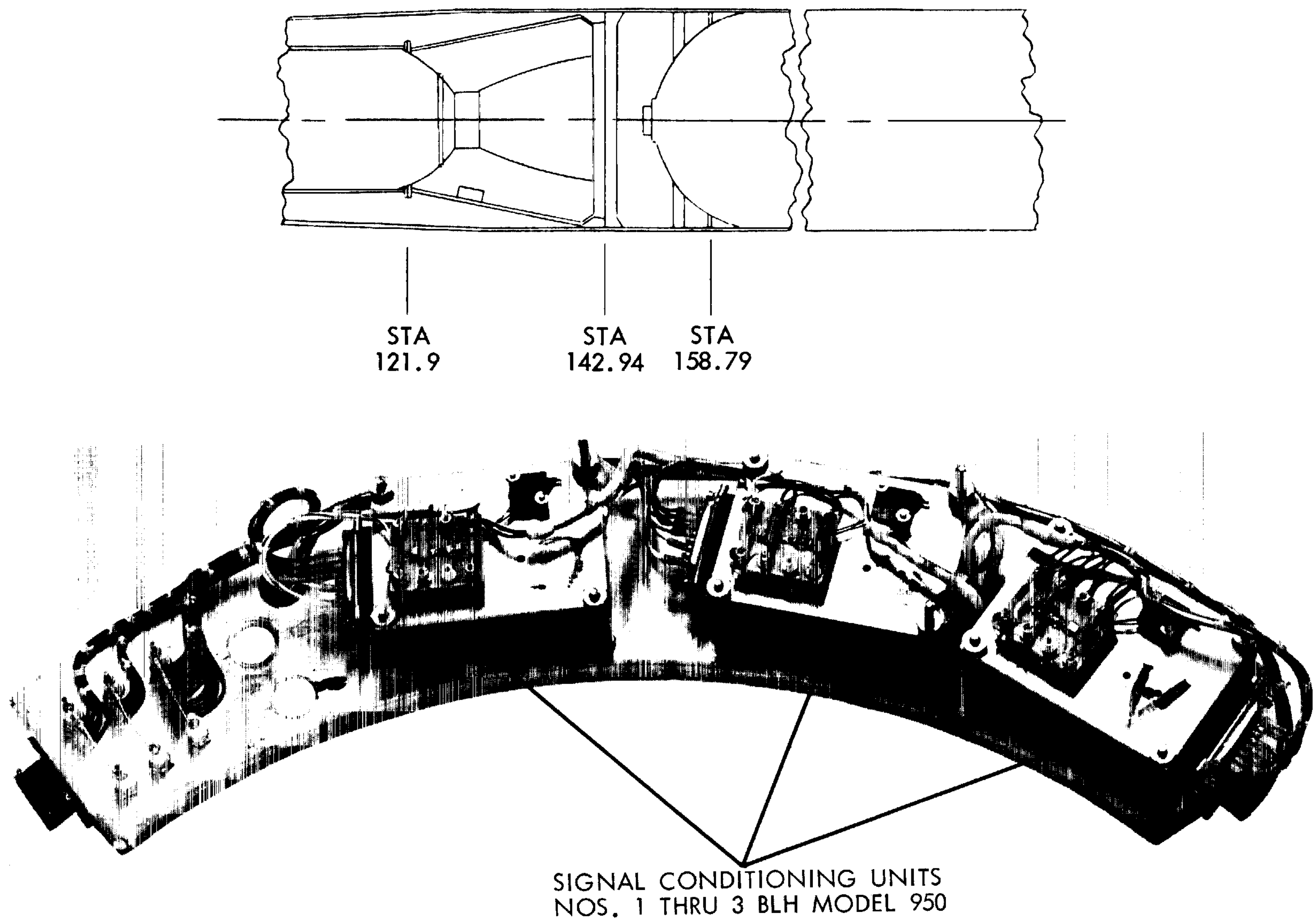
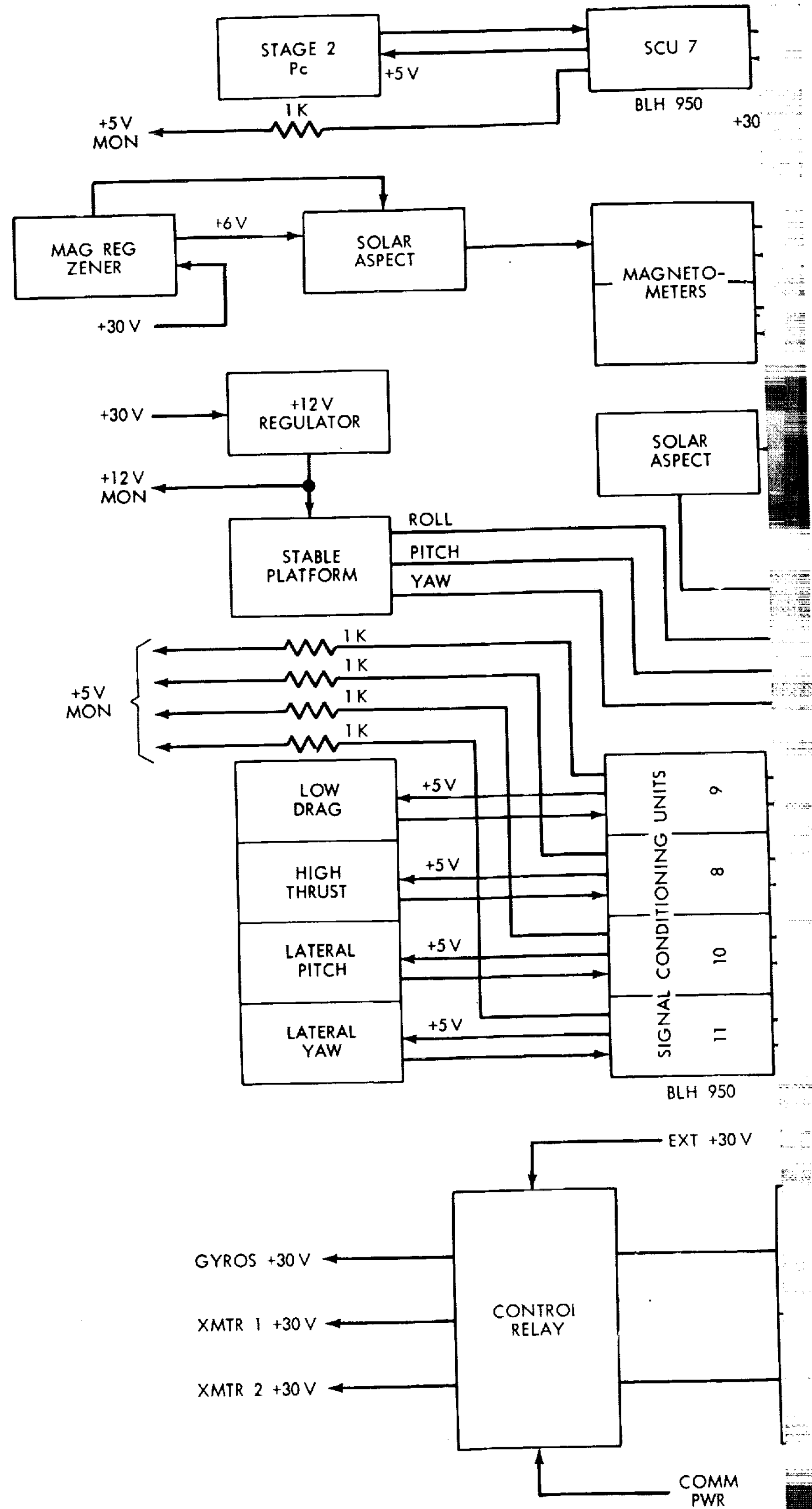


Figure 20. Stage II Monitor Deck Installations



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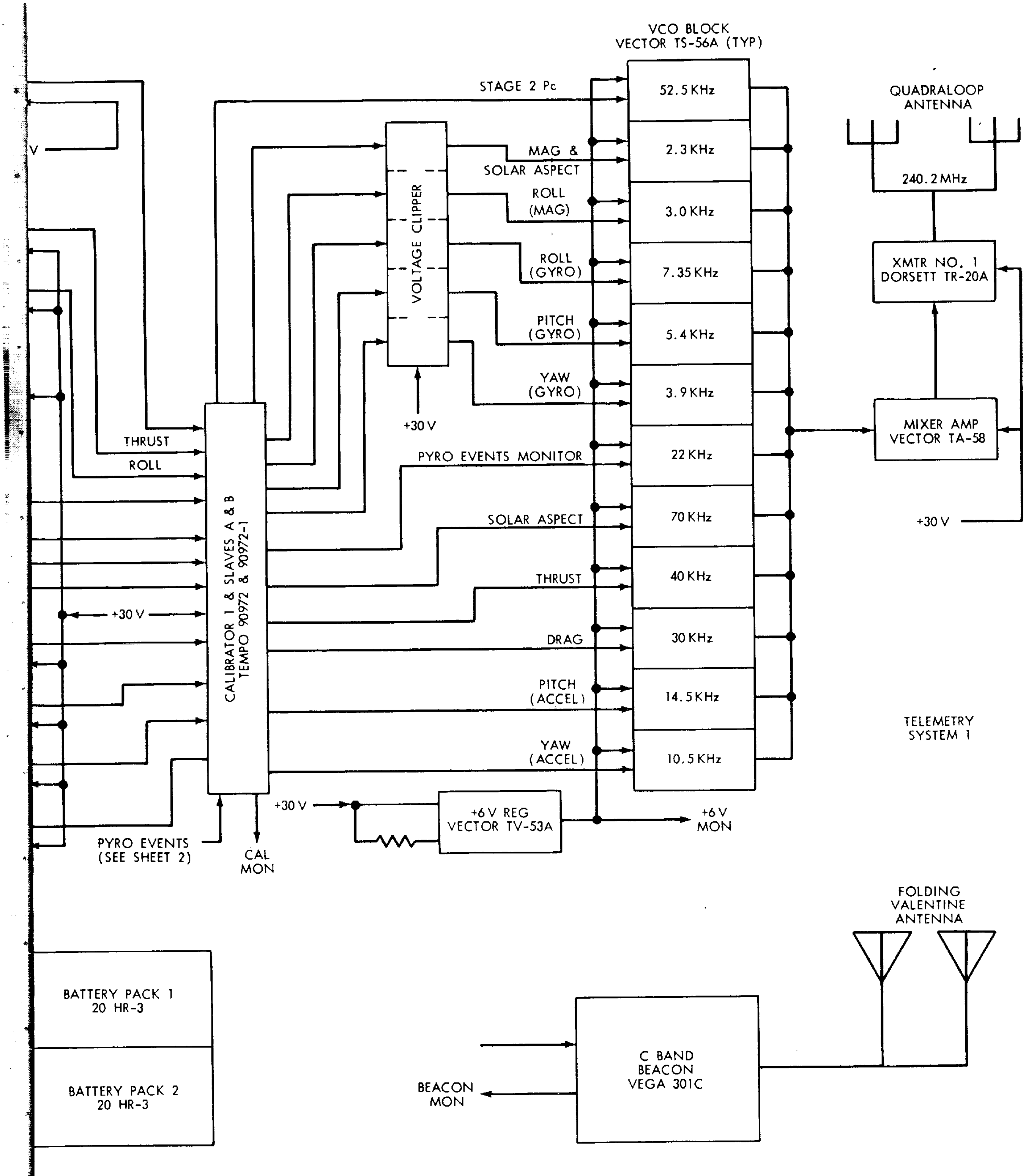

Figure 21. Stage II Telemetry System 1, Simplified Block Diagram

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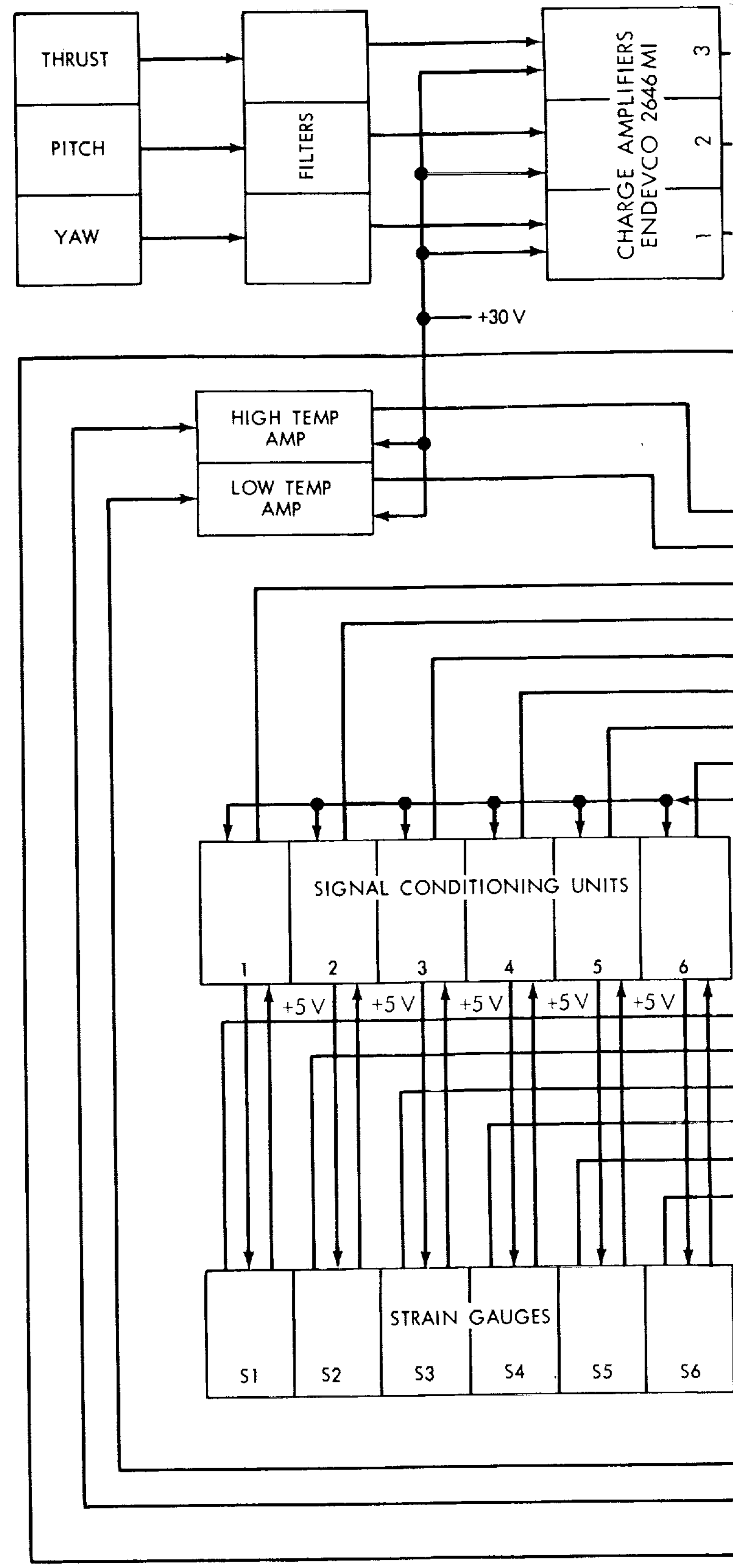

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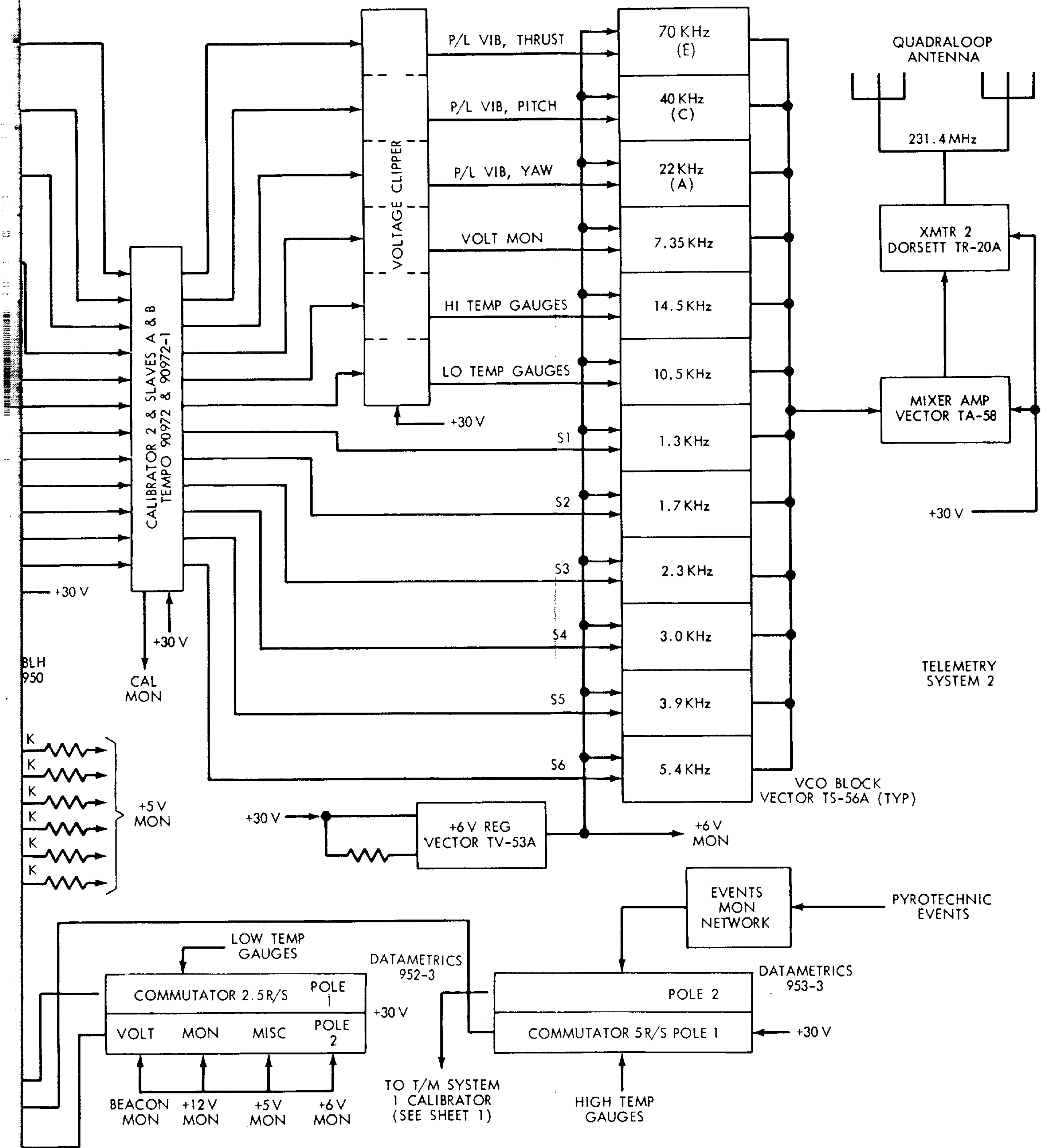

Figure 22. Stage II Telemetry System 2, Simplified Block Diagram

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Each channel had a deviation in frequency of ±7.5 percent. Inflight calibration of all channels was provided by a Tempo Model 90972 calibrator and two associated slave units. Channel 14, alloted to pyrotechnic events data, was commutated by a Datacell Model 953-3 commutator at 5 revolutions per second. Table 6 lists the Channel 14 allocations.

Table 6

TELEMETRY SYSTEM 1, COMMUTATED CHANNEL 14 ALLOCATIONS

SEGMENT	ALLOCATION
1, 28*	Ground
2	+5 volts dc Calibrate
3, 8, 15, 20, 27*	E_1
4, 9, 16, 23*	E_2
5, 10, 17, 24*	E_A (E_3 + E_4)
6, 13, 18, 25*	E_5
7, 14, 19, 26*	E_B (E_7 + E_8)
11	+2 volts dc Calibrate
12	+3 volts dc Calibrate
21	+4 volts dc Calibrate
22	+1 volts dc Calibrate

*Cross-strapped

Legend:

E_1 - Thrust Pressure Switch-Make

E_2 - Thrust Pressure Switch-Break

E_3 - Spin Rocket 1

E_4 - Spin Rocket 2

E_5 - Explosive Bolt

E_6 - Explosive Bolt Backup (Interstage T/M)

E_7 - Stage II Ignition 1

E_8 - Stage II Ignition 2

Table 7 lists the VCO IRIG band parameters of Telemetry System 2. Vibration data were assigned to subcarrier Channels E, C, and A, while 13 through 5 were allocated to strain and temperature information. Channel frequency deviation for the numbered bands was ±7.5 percent; for the lettered, or wide-band channels, deviation was ±15 percent.

Table 7
TELEMETRY SYSTEM 2, VCO IRIG BAND PARAMETERS

FREQUENCY (KHz)	IRIG BAND	ALLOCATION
70.0	E	Payload Vibration, Thrust ±20g
40.0	C	Payload Vibration, Pitch ±10g
22.0	A	Payload Vibration, Yaw ±10g
14.5	13	High Temperature, Commutated 0 to 1000° F
10.5	12	Low Temperature, Commutated 0 to 600° F
7.35	11	Voltage Monitor, Commutated 0 to 5 V
5.4	10	Strain, Payload Support ±5000 microinches/inch
3.9	9	Strain, Payload Support ±5000 microinches/inch
3.0	8	Strain, Payload Support ±5000 microinches/inch
2.3	7	Strain, Stage II Skirt ±5000 microinches/inch
1.7	6	Strain, Stage II Skirt ±5000 microinches/inch
1.3	5	Strain, Stage II Skirt ±5000 microinches/inch

Inflight calibration was provided to all channels by a calibration and slave unit system similar to that in Telemetry System 1. High-temperature transducer data was commutated at 5 revolutions per second on Channel 13 (see Table 8), while low temperature transducer data was commutated on Channel 12 (see Table 9) at 2.5 revolutions per second.

Table 8

TELEMETRY SYSTEM 2, COMMUTATED CHANNEL 13 ALLOCATIONS

SEGMENT	ALLOCATION	SEGMENT	ALLOCATION
1	150 ohm Calibrate	8, 18, 28*	T14
2	125 ohm Calibrate	9, 19*	T15
3, 13, 23*	T4	10, 20*	T16
4, 14, 24*	T5	11	100 ohm Calibrate
5, 15, 25*	T11	12	75 ohm Calibrate
6, 16, 26*	T12	21	50 ohm Calibrate
7, 17, 27*	T13	22	Ground

*Cross-strapped High Temperature (0-1000°F) Gauges

Gauge Locations:

T4 - Forward payload extension (inside)

T5 - Aft payload extension (inside)

T11 - Stage II motor dome (A)

T12 - Stage II motor dome (B)

T13 - Stage II motor skirt (A)

T14 - Stage II motor skirt (B)

T15 - Stage II exit cone (A)

T16 - Stage II exit cone (B)

Table 9
TELEMETRY SYSTEM 2, COMMUTATED CHANNEL 12 ALLOCATIONS

SEGMENT	ALLOCATION	SEGMENT	ALLOCATION
1	800 ohm Calibrate	8, 18, 28*	T8
2	750 ohm Calibrate	9, 19*	T9
3, 13, 23*	T1	10, 20*	T10
4, 14, 24*	T2	11	675 ohm Calibrate
5, 15, 25*	T3	12	600 ohm Calibrate
6, 16, 26*	T4	21	525 ohm Calibrate
7, 17, 27*	T5	22	Ground

*Cross-strapped Low Temperature (0-600°F) Gauges

Gauge Locations:

T1 - Nose Cone, tip (inside)

T2 - Nose Cone, inside (mid-way)

T3 - Nose Cone, normal to clamshell (inside)

T6 - Top Instrumentation Rack

T7 - Middle Instrumentation Rack

T8 - Bottom Instrumentation Rack

T9 - Air Temperature Gauge 1

T10 - Air Temperature Gauge 2

Signal conditioning unit (SCU) voltages, and other significant voltages, were monitored and commutated at 2.5 revolutions per second on Channel 11. These are tabulated in Table 10, with the different SCU parameters listed in the accompanying footnote.

Table 10

TELEMETRY SYSTEM 2, COMMUTATED CHANNEL 11 ALLOCATIONS

SEGMENT	ALLOCATION	SEGMENT	ALLOCATION
1	Ground	14	SCU 3
2	Inst. +30 volt Bus 1	15	SCU 4
3	Inst. +30 volt Bus 2	16	+3 volts dc Calibrate
4, 27*	Beacon Monitor	17	SCU 5
5	SCU 12	18	SCU 6
6	+1 volt dc Calibrate	19	SCU 7
7	+12 volts dc Gyro	20	SCU 8
8	+6 volts dc Monitor TM 1	21	+4 volts dc Calibrate
9	+6 volts dc Monitor TM 2	22	SCU 9
10, 26*	+5 volts dc Calibrate	23	SCU 10
11	+2 volts dc Calibrate	24	SCU 11
12	SCU 1	25	+1 volt (Pedestal)
13	SCU 2	28	SCU 13

*Cross-strapped

Signal Conditioning Unit (SCU) Frequency and Data Allocations:

SCU 1, Strain, Stage II Motor Skirt (A) (1.3 KHz)

SCU 2, Strain, Stage II Motor Skirt (B) (1.7 KHz)

SCU 3, Strain, Stage II Motor Skirt (C) (2.3 KHz)

SCU 4, Strain, P/L Support A (3.0 KHz)

SCU 5, Strain, P/L Support B (3.9 KHz)

SCU 6, Strain, P/L Support C (5.4 KHz)

SCU 7, Stage II, P_c (52.5 KHz)

SCU 8, Thrust $\ddot{X}$ (40 KHz)

SCU 9, Low Drag $\ddot{X}$ (30 KHz)

SCU 10, Pitch $\ddot{X}$ (14.5 KHz)

SCU 11, Yaw $\ddot{X}$ (10.5 KHz)

SCU 12, High Temp. (14.5 KHz)

SCU 13, Low Temp. (10.5 KHz)

RADAR TRANSPONDER

A Vega Model 301C radar transponder was mounted on deck 4 of the payload (Figure 23) to ensure accurate payload tracking at high altitudes. The C-band beacon transmitter pulsed-output power was about 425 watts peak. Beacon transmitting and receiving frequencies were 5600 megahertz and 5486 megahertz, respectively. Two folding valentine antennas, mounted on the Stage II skin, were used by the beacon. The two Stage II telemetry systems each employed two quadraloop antennas similarly located. Power for all Stage II components was derived from battery boxes 1 and 2, located on deck 4, each containing 20 Yardney HR-3DC Silvercels.

INTERSTAGE TELEMETRY SYSTEM

The interstage telemetry (Figures 24a and 24b) consisted of wafer-shaped voltage-controlled subcarrier oscillators, a mixer amplifier, voltage regulator, and an FM transmitter. All components were plug-in modules, with integral connectors to minimize space and weight requirements of mounting and interconnection. Operation of this system (Figure 25) was similar to that of the Stage II systems (Figures 21 and 22). Table 11 lists the interstage telemetry VCO allocations and associated IRIG bands.

Table 11
INTERSTAGE TELEMETRY SYSTEM, VCO IRIG BAND PARAMETERS

FREQUENCY (KHz)*	IRIG BAND	ALLOCATION
70.0	18	Chamber Pressure, Stage I 0 to 1000 psia
52.5	17	Motor Vibration, Thrust -5g to +15g
40.0	16	Motor Vibration, Yaw
30.0	15	Clamshell Vibration, Pitch ±10g
22.0	14	Temperature, Commutated 0-1000° F
14.5	13	Yaw Ogive Gauge & Monitor ±7.5 degrees
10.5	12	Clamshell Pressure 0-15 psia
7.35	11	Pitch Ogive Gauge ±7.5 degrees
5.4	10	Clamshell Position, Pitch ±5 inches
3.9	9	Clamshell Position, Yaw ±5 inches

*±7.5% Deviation

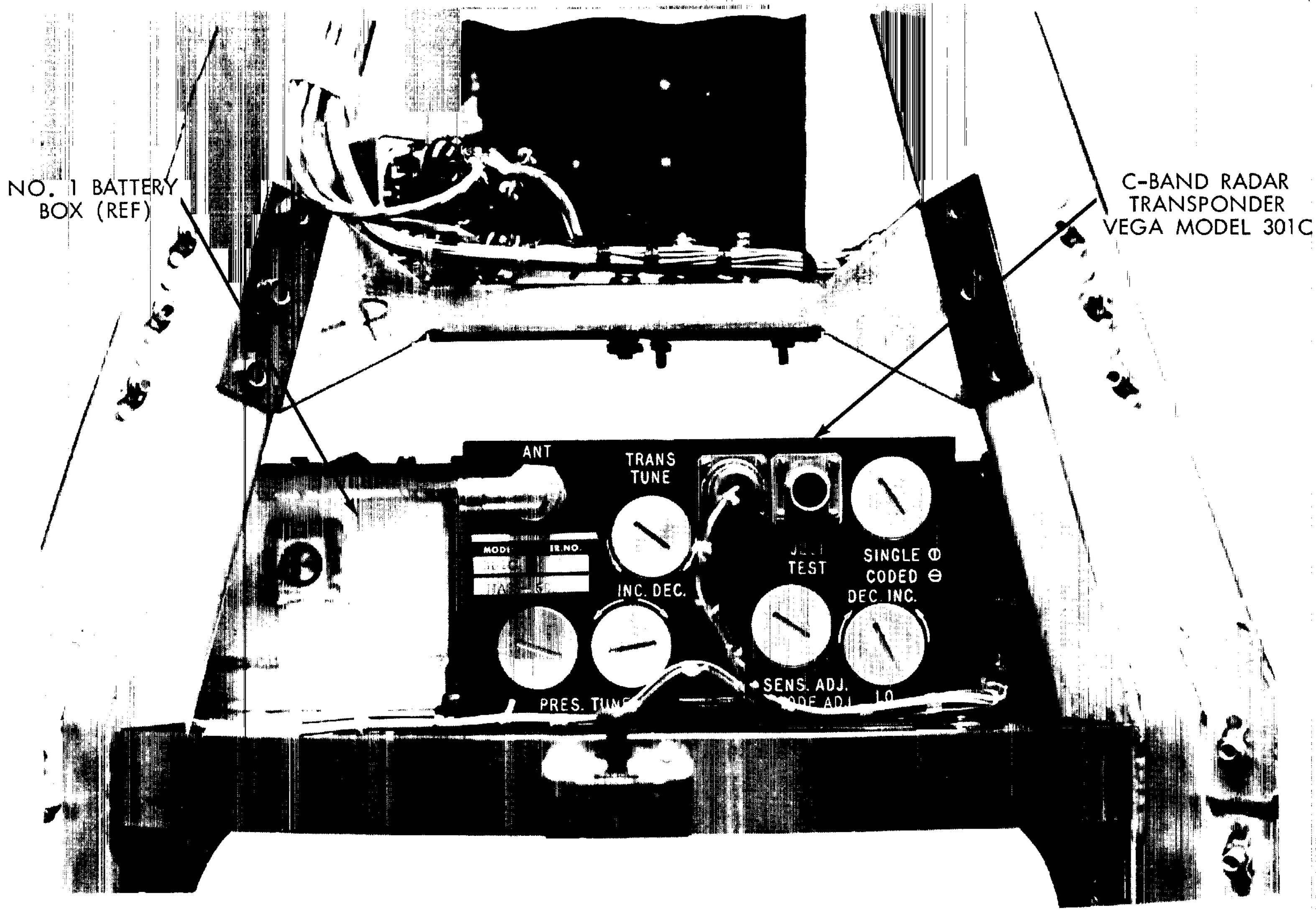


Figure 23. Radar Transponder on Deck 4

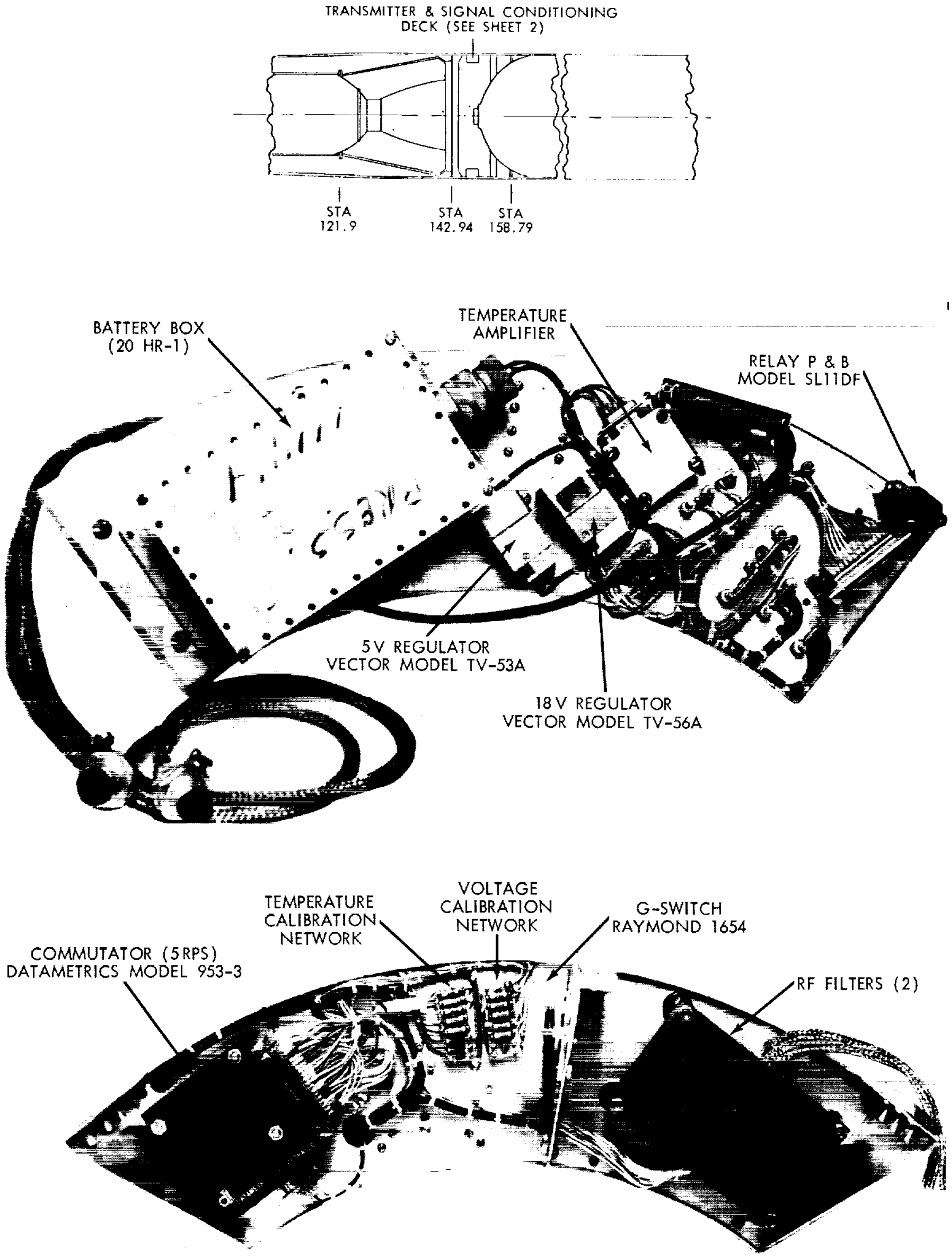


Figure 24a. Interstage Telemetry System Components

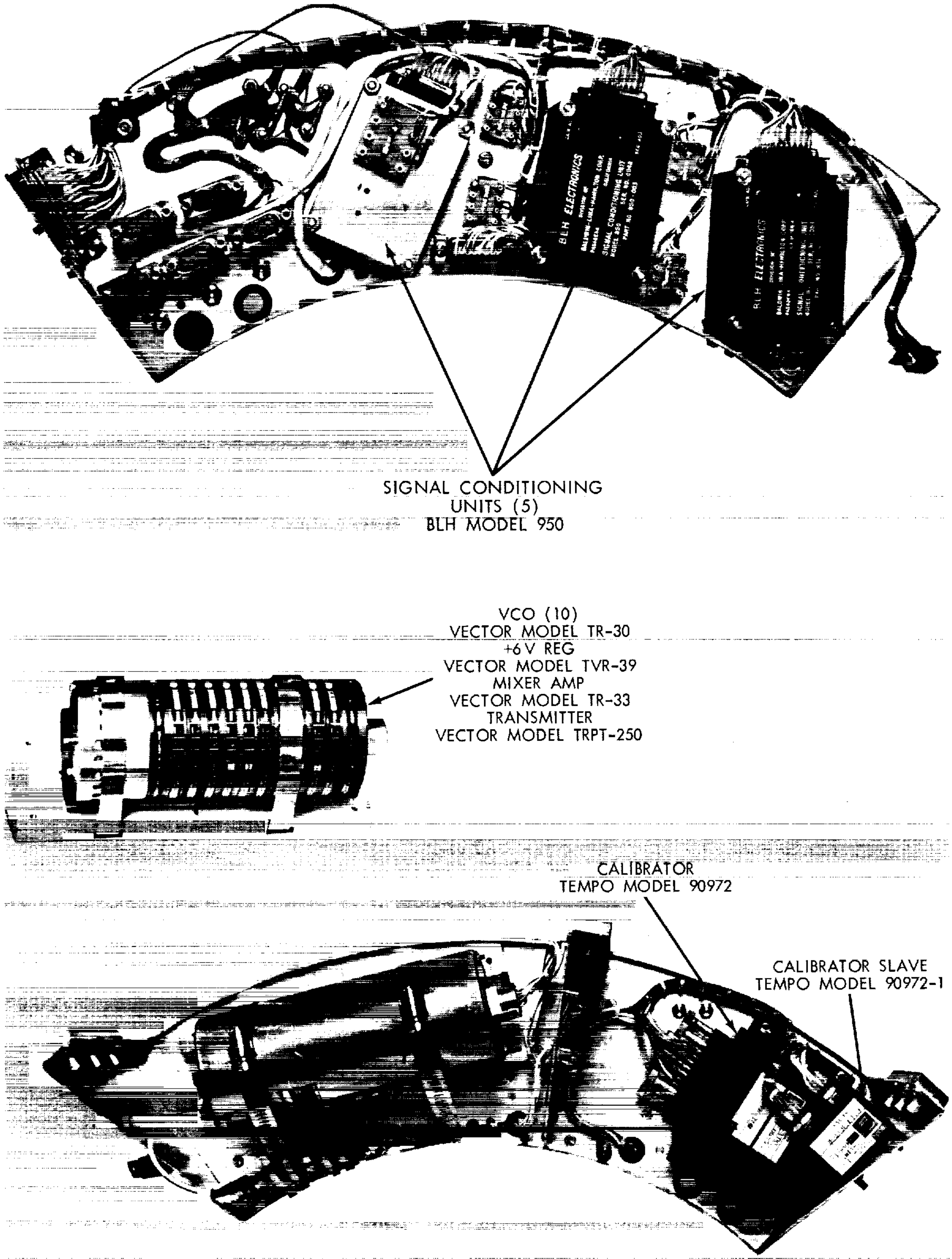
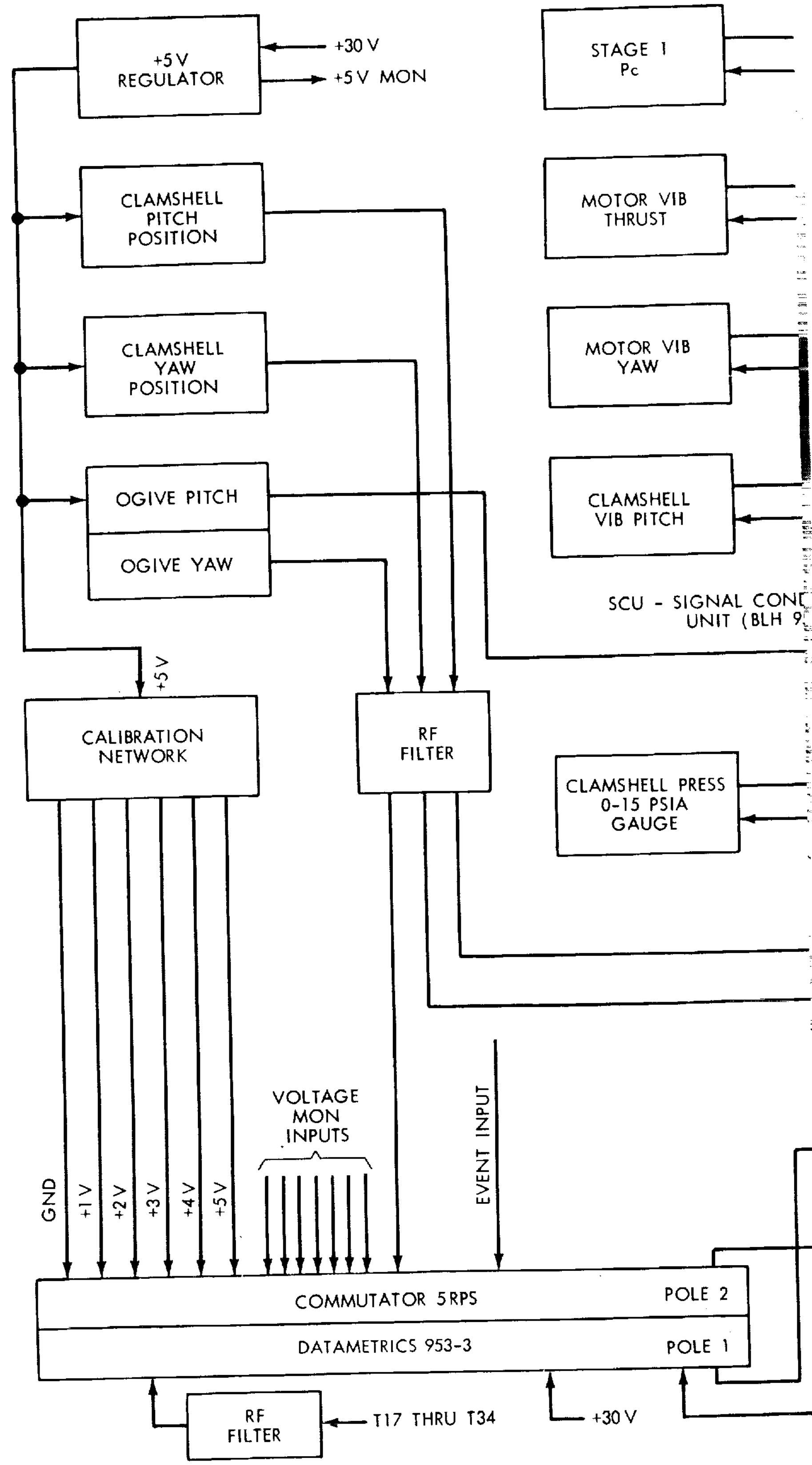


Figure 24b. Interstage Telemetry System Components



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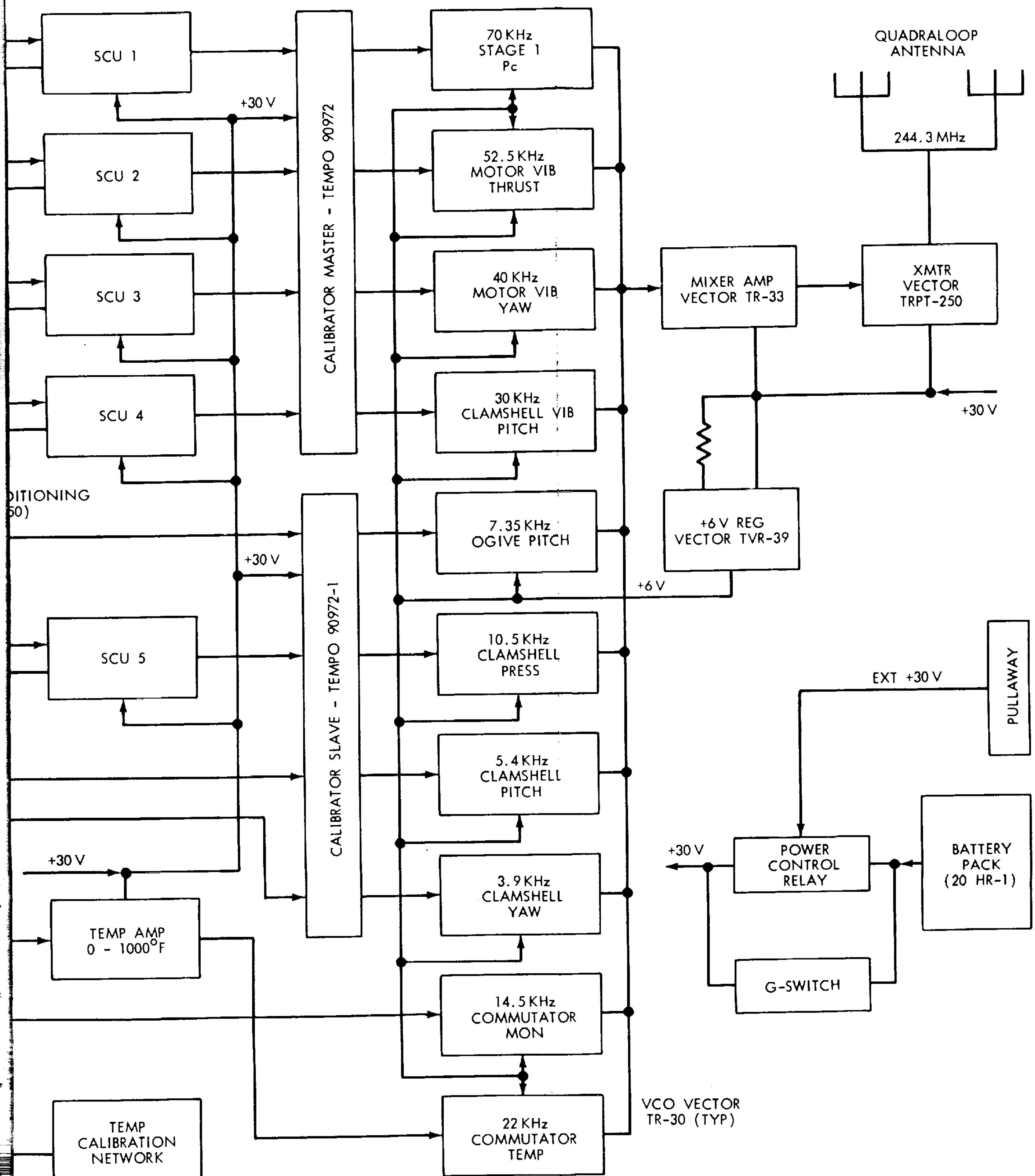

Figure 25. Interstage Telemetry System, Simplified Block Diagram

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After the instrumentation outputs had been amplified (where necessary) to a level sufficient for VCO modulation, they were applied to their respective Tempo Model 90972 inflight calibrator, or associated Model 90972-1 slave channels. Each data channel was sequentially switched from data to a precision staircase-voltage generator, calibrating each VCO channel over the range from 0 to 5 volts, in one-volt steps. When calibration of one channel was completed, that channel was switched back to transmit data, and the next channel was calibrated. The calibration cycle was adjusted to allow 90 seconds of data transmission on each channel before calibration.

With the exception of bands 14 and 13, inflight calibration was provided to all channels by a Tempo Model 90972 calibrator and slave unit. Calibration of commutated bands 14 and 13 was provided by passive resistor networks located beneath the power supply deck. Table 12 is a listing of high temperature transducers commutated on band 14 while Table 13 lists the band 13 allocations. Both bands were commutated at 5 revolutions per second by a Datametrics Model 953-3 commutator.

Interstage +30 volts dc telemetry power was from 20 Yardney HR-1 DC Silvercels located on the power supply deck. Data transmission was on 244.3 megahertz, using two quadraloop antennas located 180 degrees apart on Stage I.

The calibrator output signal was applied to a Vector Model TR-30 voltage-controlled oscillator (VCO), where the subcarrier frequency was generated. Fully transistorized to minimize size and weight, each VCO consists of an amplifier and multivibrator circuit in addition to an output band-pass filter to suppress harmonics generated by the multivibrator during the frequency modulation process. VCO operating power (6 volts dc) was supplied by a Vector Model TVR-39 voltage regulator.

The frequency-modulated VCO output voltage was then multiplexed and amplified by a Vector Model TR-33 mixer amplifier. Voltage regulation was such that a ±10 percent change in input voltage resulted in less than a ±0.1 percent change in output voltage.

The multiplexed signal from the mixer amplifier was then applied to a Vector Model TRPT-250 RF transmitter which is a transistorized phase-modulated crystal-controlled unit, with a rated nominal output of 0.25 watt. (Note that the output of the Stage II Dorsett Model TR-20A transmitters was 4 watts.) Within the transmitter, the crystal controlled oscillator output is capacitively coupled to the phase modulator. The phase modulated output is then transformer-coupled to the first of three tripler stages. The modulated carrier is doubled to the proper frequency and applied through the power amplifier to the antenna system.

Table 12
INTERSTAGE TELEMETRY SYSTEM,
COMMUTATED CHANNEL 14 ALLOCATIONS

SEGMENT	ALLOCATION	SEGMENT	ALLOCATION
1	150 ohm Calibrate	13, 25*	T24
2	125 ohm Calibrate	14, 26*	T25
3	100 ohm Calibrate	15, 27*	T26
4	75 ohm Calibrate	16, 28*	T27
5	50 ohm Calibrate	17	T28
6	T17	18	T29
7	T18	19	T30
8	T19	20	T31
9	T20	21	T32
10	T21	22	T33
11	T22	23	T34
12	T23	24	Ground

*Cross-strapped

Interstage High Temperature (0-1000° F) Gauge Locations:

T17 Clamshell tip (inside)
T18 Clamshell Station 34.4 inches (outside)
T19 Clamshell Station 34.4 inches (inside)
T20 Clamshell midway (outside)
T21 Clamshell midway (inside)
T22 Stage I motor dome (A)
T23 Stage I motor dome (B)
T24 Stage I exit cone (A)
T25 Stage I exit cone (B)

T26 Stage I tail fin (A)
T27 Stage I tail fin (B)
T28 Stage I tail fin (C)
T29 Stage I tail fin (D)
T30 Stage I tail fin (E)
T31 Stage I tail fin (F)
T32 Stage I tail fin (G)
T33 Stage I tail fin (H)
T34 Stage I tail fin (I)

Tables 14 and 15 contain general physical and performance specifications for components of the Interstage and Stage II telemetry systems. Tests were conducted on all components by the Sounding Rocket Instrumentation Section to ensure proper operation and conformance to design specifications.

Table 13
INTERSTAGE TELEMETRY SYSTEM,
COMMUTATED CHANNEL 13 ALLOCATIONS

SEGMENT	ALLOCATION	SEGMENT	ALLOCATION
1	Ground	13	+5 volts dc Regulator
2, 6, 10, 14, 18, 22, 26*	Yaw Ogive	16	+4 volts dc Calibrate
3	Pyro Event 6 (E6)	17	SCU 1 (Pc)
4	+1 volt dc Calibrate	20	+5 volts dc Calibrate
5	Instrumentation +30 volts dc	21	SCU 2 (Vibration Thrust)
7, 11, 15, 19, 23*	E6	24	SCU 3 (Vibration Yaw)
8	+2 volts dc Calibrate	25	SCU 4 (Clamshell Vibration)
9	+6 volts dc reg. T/M No. 3	27	±18 volts dc Monitor
12	+3 volts dc Calibrate	28	SCU 5 (Clamshell Pressure)

*Cross-strapped

E6 - Explosive Bolt Backup

Figure 26 shows a typical arrangement of SRIS test equipment during component testing. Figures 27 through 30 contain the block diagrams used for testing the VCO's, voltage regulators, mixer amplifiers, and transmitters.

Output transmitter power of the Interstage telemetry system was radiated by a pair of 244.3 megahertz quadraloop antennas located 180 degrees apart on the Stage I motor casing. The Stage II telemetry systems utilized four similar antennas to radiate on 240.2 megahertz and 231.4 megahertz. These antennas were mounted at 90 degree intervals on the payload extension, beneath the clamshell heat shield. Quadraloop antennas, which have a history of successful operation with sounding rocket payloads, offered the aerodynamic advantage of close mounting to the rocket skin. Appendix B contains antenna power contour

Table 14
INTERSTAGE TELEMETRY SYSTEM, COMPONENT SPECIFICATIONS

TRANSMITTER (VECTOR MODEL TRPT-250)	
Size	2.6 inch diameter x 1.5 inch height
Weight	8 ounces
Power Output	0.25 watts, nominal
Distortion	3% maximum
Frequency Range	215 to 260 watts, nominal
Modulation Frequency Range	100 hertz to 200 kilohertz
Power Requirements	+28 volts dc ±10% at 80 milliamperes
MIXER AMPLIFIER (VECTOR MODEL TR-33)	
Size	2.6 inch diameter x 7/16 inch height
Weight	2.2 ounces
Frequency Response	±0.5 decibel from 100 to 100,000 hertz
Gain	Adjustable to 20X
Power Requirements	+28 volts dc at 20 milliamperes, nominal
VCO (VECTOR MODEL TR-30)	
Size	2.6 inch diameter x 7/16 inch height
Weight	2.2 ounces
Linearity	Less than ±0.75%
Amplitude Modulation	Less than ±10%
Power Requirements	6 volts dc ±0.1% at 5 milliamperes
VOLTAGE REGULATOR (VECTOR MODEL TVR-39)	
Size	2.6 inch diameter x 1/2 inch height
Weight	2.75 ounces
Output Voltage	6 volts dc at 200 milliamperes
Regulation	Maximum 0.1% output voltage change for ±10% input voltage change
Power Requirements	+28 volts dc ±10% at 245 milliamperes

Table 15

STAGE II TELEMETRY SYSTEM, COMPONENT SPECIFICATIONS

TRANSMITTER (DORSETT MODEL TR-20A)	
Size	3 inches x 1.75 inches x 4 inches
Weight	14 ounces
Power Output	4 watts
Distortion	1% maximum
Frequency Range	225 to 260 megahertz
Modulation Frequency Range	50 hertz to 100 kilohertz
Power Requirements	28.8 ±4 volts dc at 1 ampere
MIXER AMPLIFIER (VECTOR MODEL TA-58)	
Size	7/8 inch x 1-1/16 inches x 1-3/8 inches
Weight	1.5 ounces
Frequency Response	±0.5 decibel maximum from 300 to 100,000 hertz
Gain	Adjustable to 15X
Power Requirements	+28 volts dc at 10 milliamperes
VCO (VECTOR MODEL TS-56A)	
Size	7/8 inch x 1-1/16 inches x 1-3/8 inches
Weight	1.75 ounces
Linearity	Less than ±0.75%
Amplitude Modulation	Less than ±10%
Power Requirements	6 volts dc ±0.1% at 5 milliamperes
VOLTAGE REGULATOR (VECTOR MODEL TV-53A)	
Size	1.415 inches x 1.11 inches x 0.925 inch
Weight	1.75 ounces
Output Voltage	6 volts dc at 200 milliamperes
Regulation	Maximum 0.1% output voltage change for ±10% input voltage change
Power Requirements	+28 volts dc ±10% at 245 milliamperes

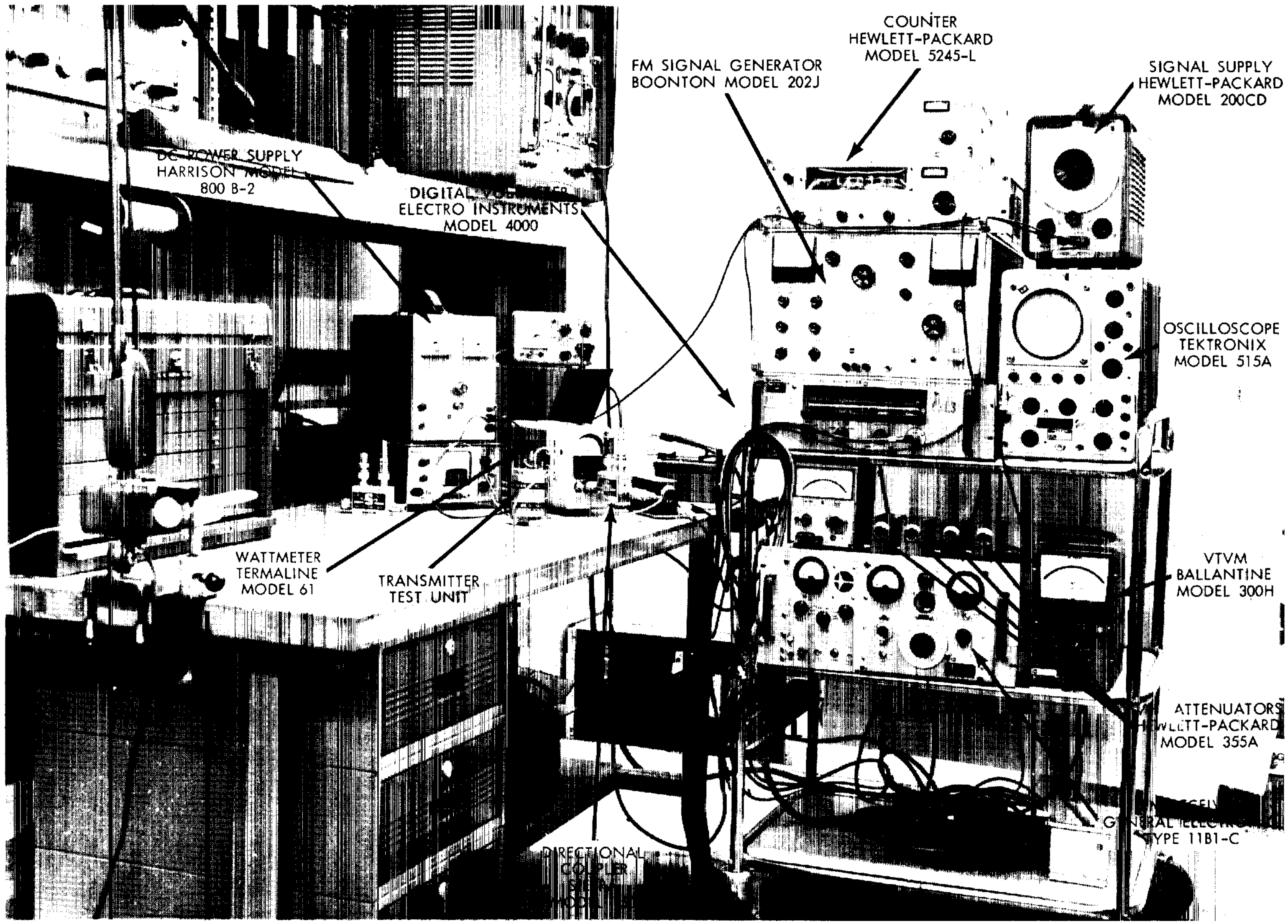


Figure 26. Instrumentation Section, Typical Test Equipment Arrangement

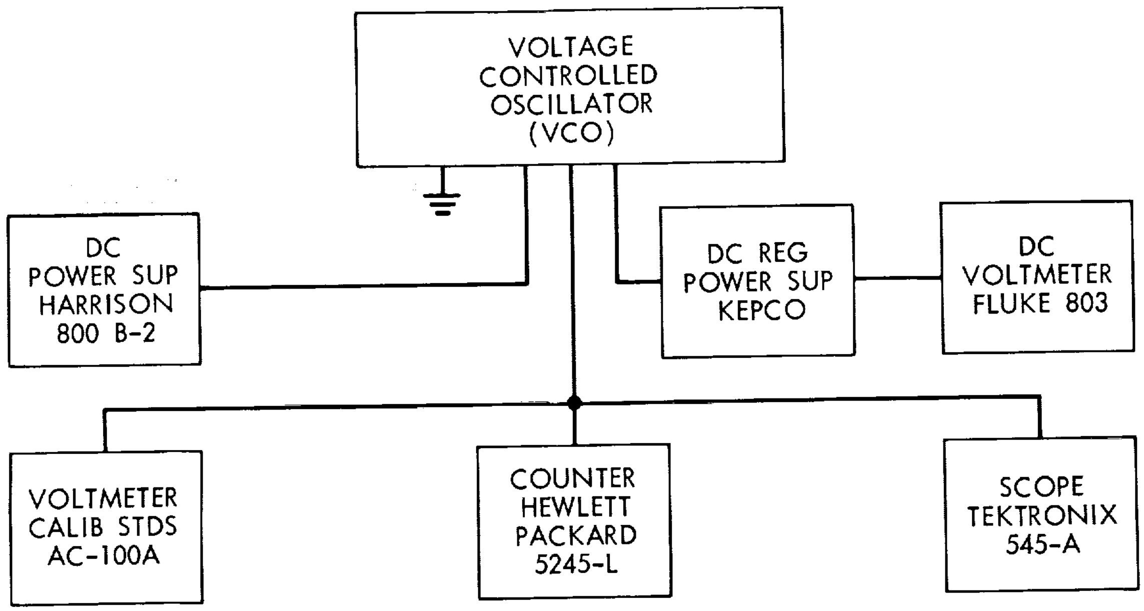


Figure 27. VCO Test, Block Diagram

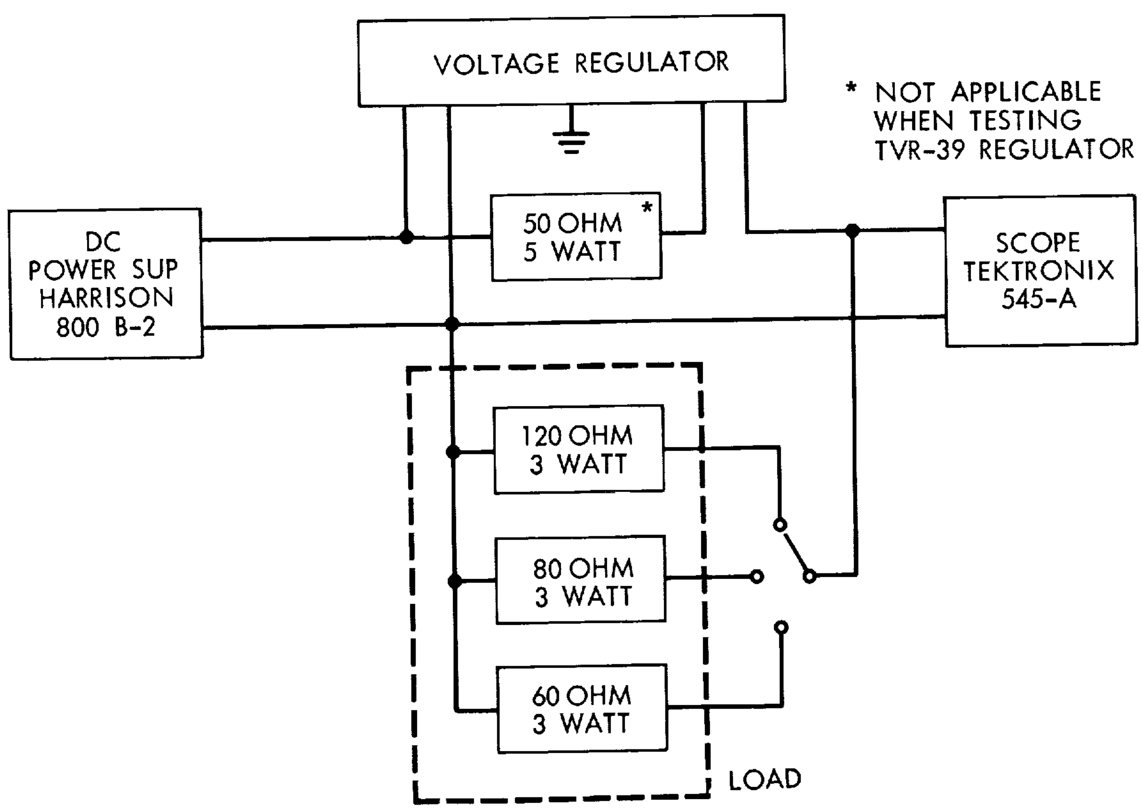


Figure 28. Voltage Regulator Test, Block Diagram

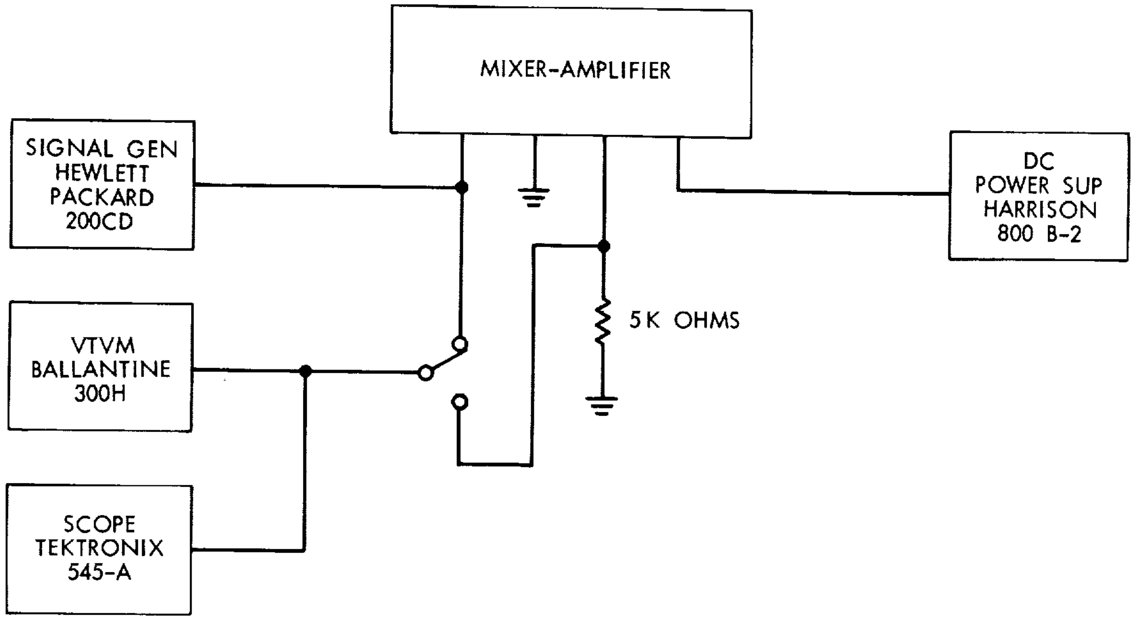


Figure 29. Mixer Amplifier Test, Block Diagram

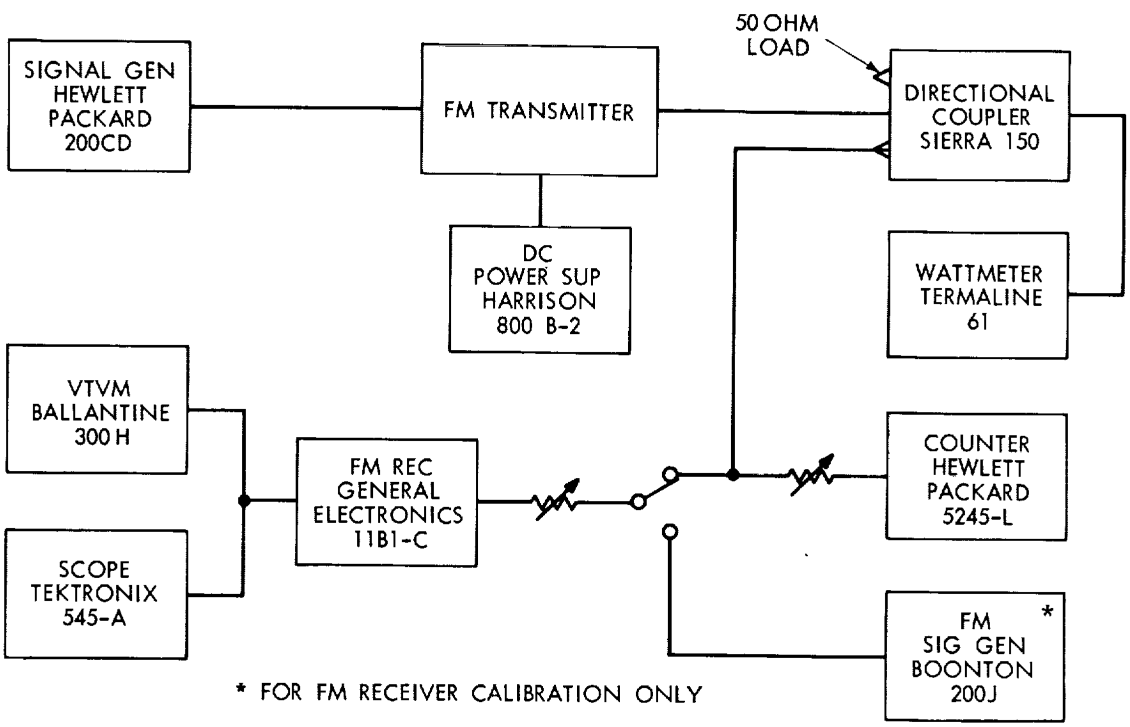


Figure 30. Transmitter Test and Alignment, Block Diagram

patterns, Smith chart plots, and representative radiation patterns for the quadraloop and radar beacon valentine antennas. Measurements of the 244.3 megahertz interstage antennas were not taken because of the relatively short transmitting distance required.

PYROTECHNIC CONTROL SYSTEM

Components for the pyrotechnic control system were located in the vehicle Interstage section (see Figure 31). The system (Figure 32) was armed prior to flight by means of a Ground Checkout Unit, which also permitted preflight testing of the operation of the sequencer unit. The sequencer unit performed the vehicle timing function for ignition of the four Stage II spin rockets, ignition of the explosive bolts for the opening of the clamshell nose cone, and ignition of the squibs for Stage II ignition.

Provision was also made for the connection of a range safety switch, to permit last minute preclusion of the Stage II pyrotechnic events. The thrust pressure switch (TPS), mounted on the Stage I motor dome, was the primary pyrotechnic control device. At Stage I pressure buildup, the TPS was operated and power was applied to relay K2, which locked and connected power for operation of relay K4 during pressure decay. At this time relay K4 locked and connected power to start timers M2, M4, and eventually M3.

In the event of TPS or electronic timer malfunction, mechanical timing, through M1, and M5 was provided to insure a proper Stage I launch sequence. Timer M1 provided firing voltage to the spin motors and Stage II ignition, 1.5 seconds after Timers M2 and M3. At 8 seconds after liftoff, this timer (M1) also applied power to relay K7, and connected the pyrotechnic monitoring circuits. Timer M5 applied firing voltage to the clamshell explosive bolts, also altitude switches in the circuit of timer M5 connected the pyrotechnic monitor for the explosive bolts at about 5000 feet altitude.

STAGE II DESPIN ASSEMBLY

A two-stage Yo-Yo type despin assembly was flown to test its effectiveness in retarding Stage II spin to a prescribed rate. Both Yo-Yo stages were located in the payload support ring (see Figure 33), and consisted of four weight and cable assemblies, two squib actuated valves, four altitude switches, and a g-timer. The two weights were attached to separate cables which were wrapped symmetrically around the outer circumference of the support ring. An inner support ring cable, tension loaded by the valve pin, held the weights in place.

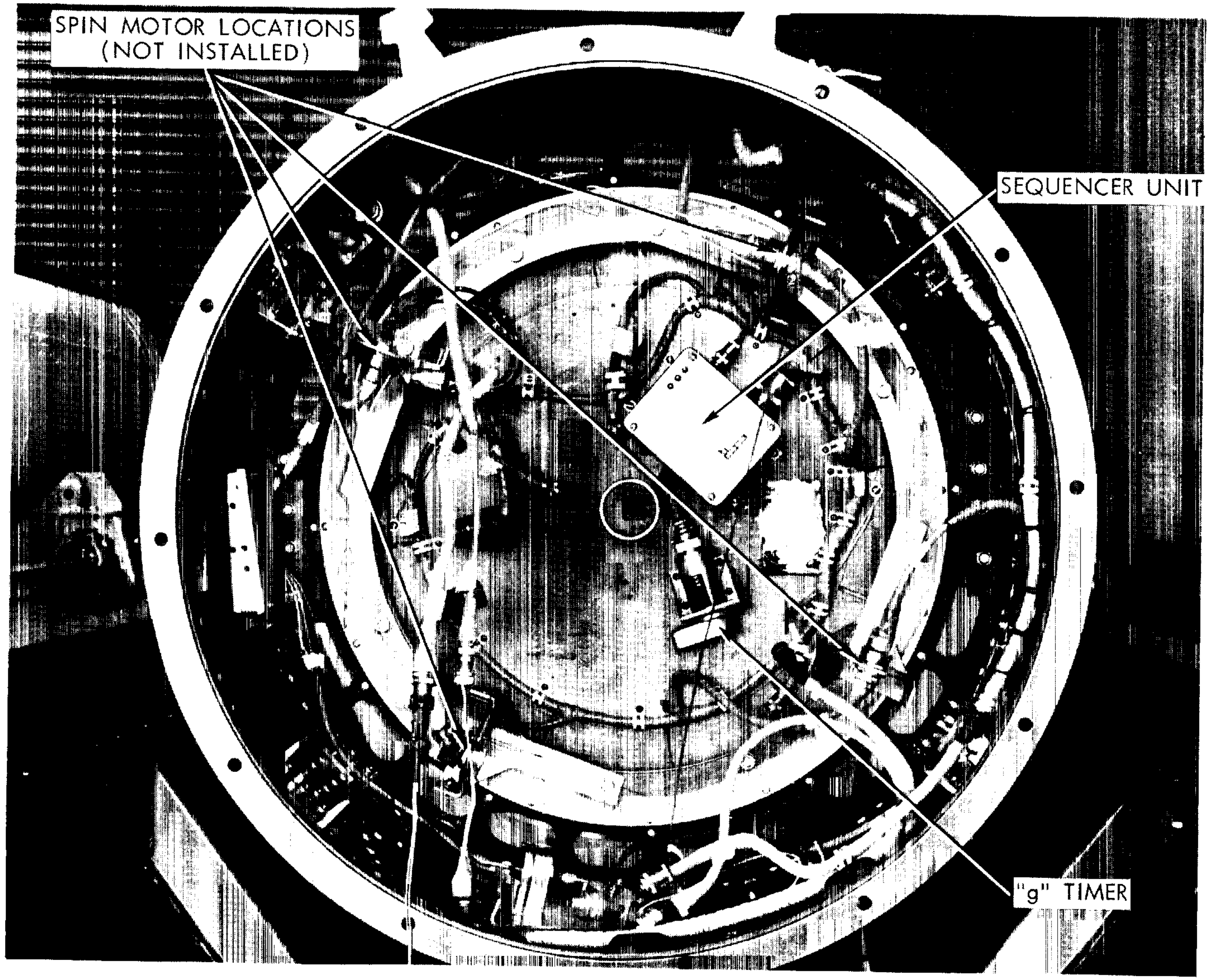


Figure 31. Pyrotechnic Control System Component Locations

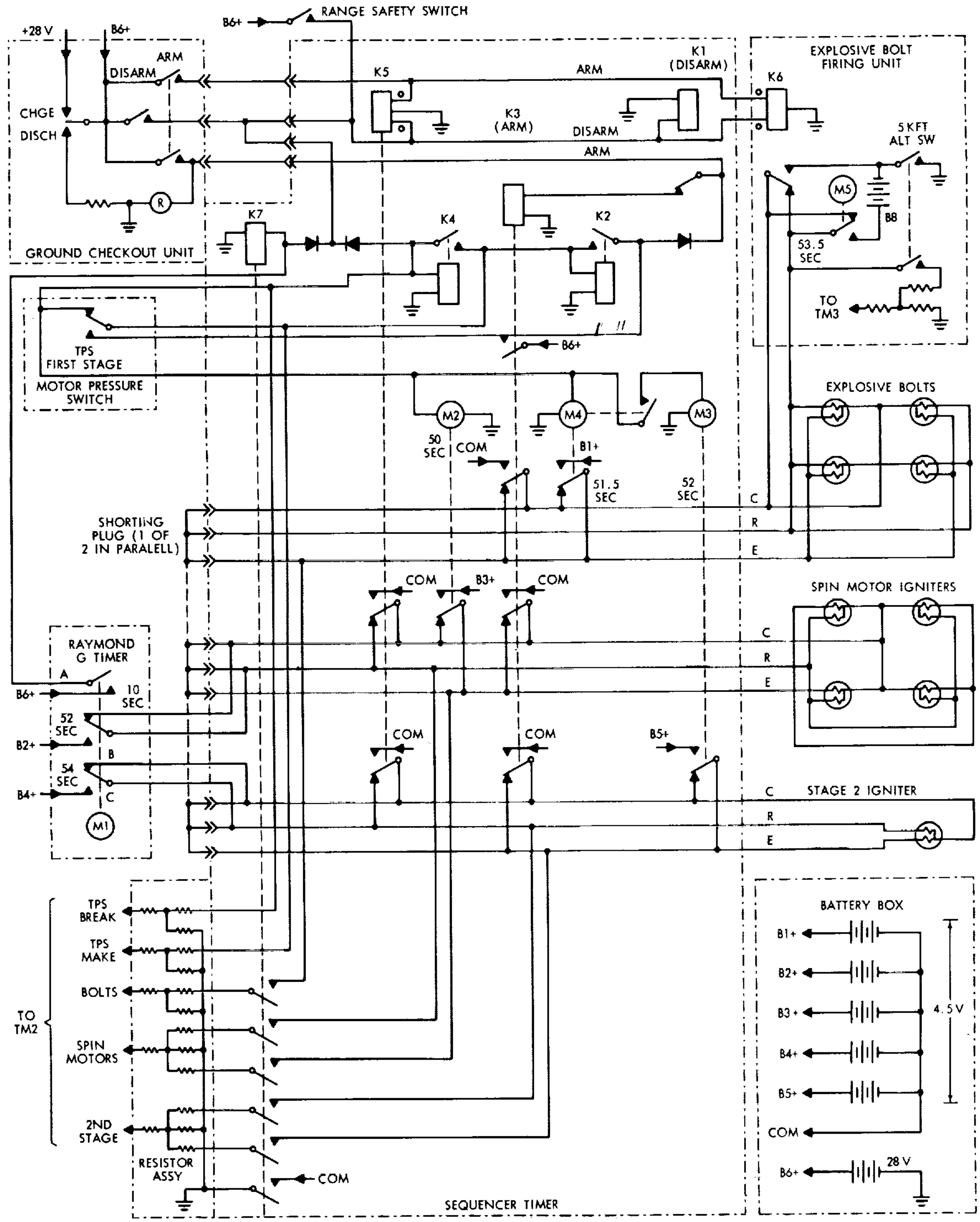
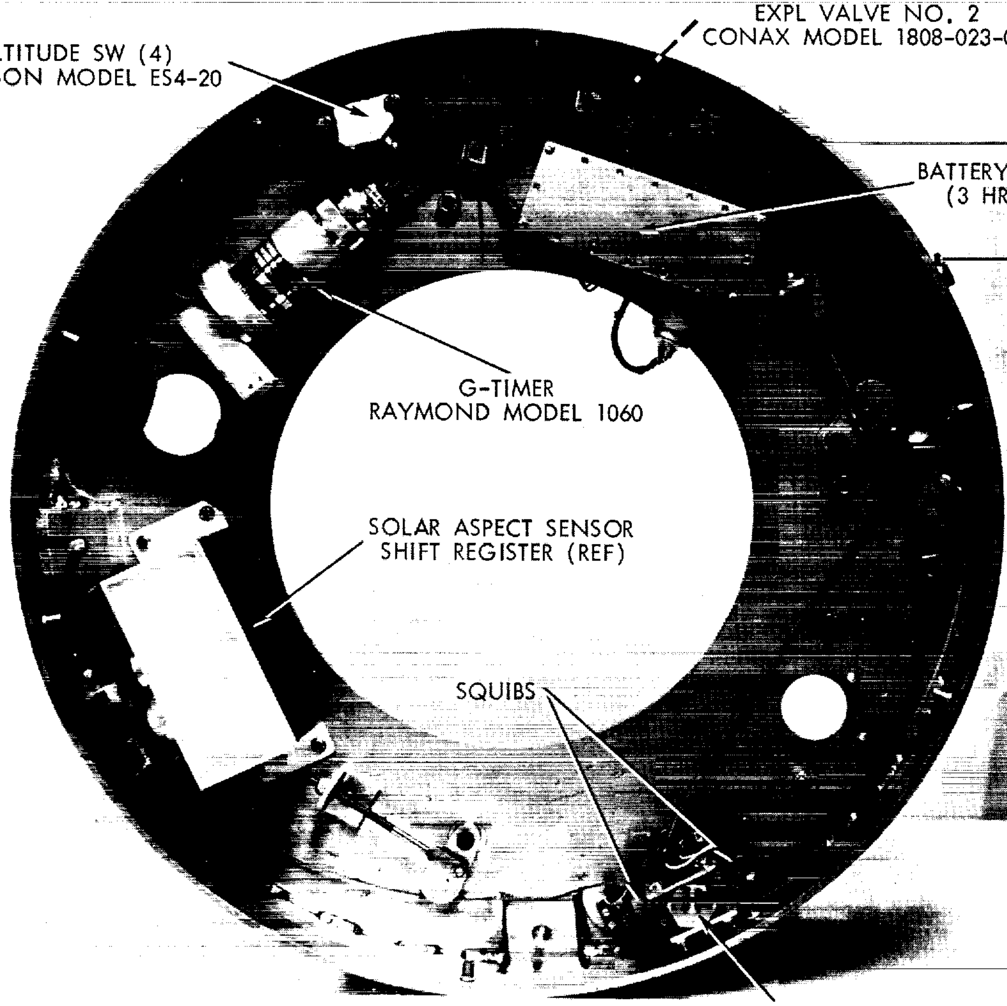


Figure 32. Pyrotechnic Control System Schematic Diagram



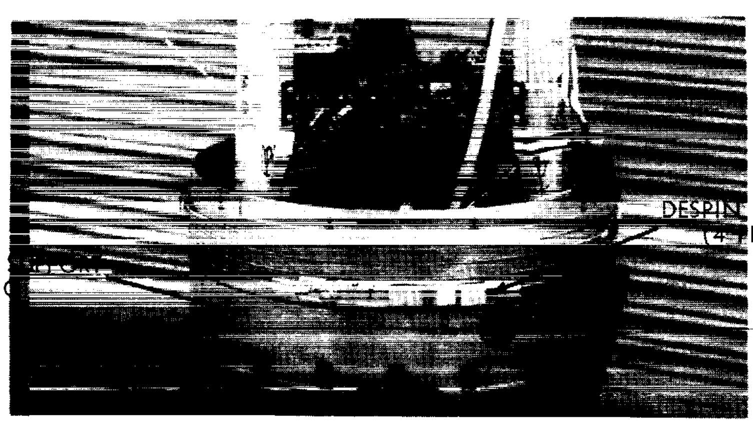


Figure 33. Yo-Yo Despin Assembly, Equipment Location

The altitude switches (a range safety requirement) functioned to preclude inadvertent despin operation at low altitudes. Switch No. 1 of the g-timer closed at T+600 seconds (see Figure 34) to detonate the valve squibs and release the two weights which retarded Stage II spin from about 12 to 9 revolutions per second. The cables and weights are then released. In a similar manner, deployment of the next two weights takes place at T+900 seconds. Stage II spin is then further reduced to 6 revolutions per second before the weights are automatically detached.

INTEGRATION

The payload component assemblies and subsystems are integrated, and their performance checked under simulated flight conditions. In addition, the telemetry systems are checked by means of the ground telemetry station to ensure that all systems are properly operating. Integration is the last functional inspection prior to shipping the payload to the launch site, therefore it is essential that any incompatibilities be discovered and remedied at this time.

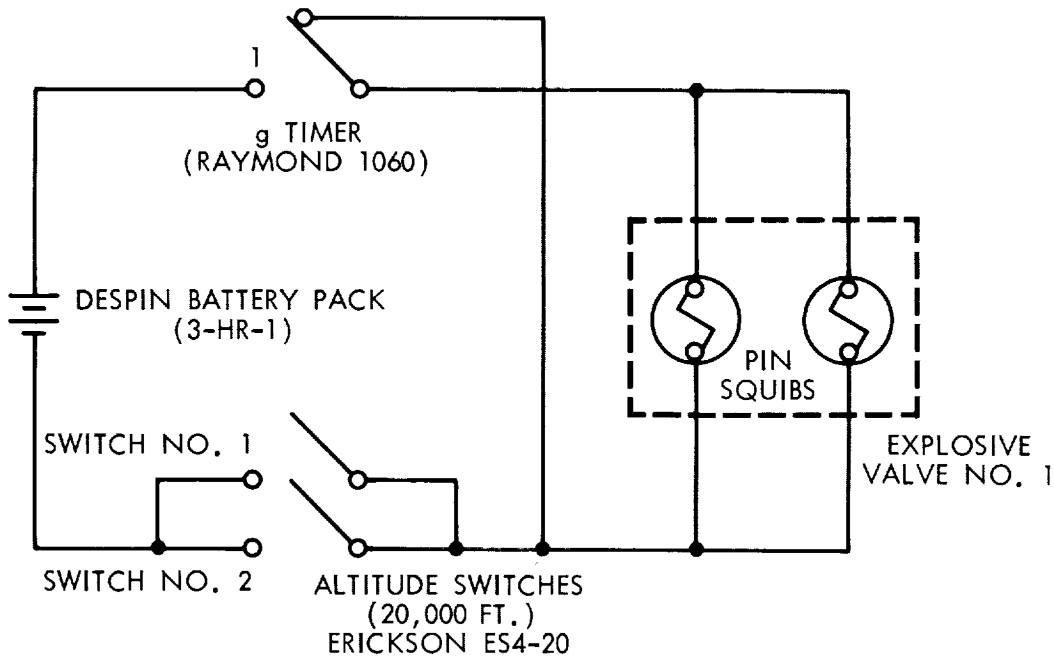
Flight 16.02 payload was successfully integrated at the GSFC Beltsville facility, using SRIS telemetry Ground Station G located within the building. No major problems were encountered and all minor difficulties were quickly resolved. Because the clamshell and nose cone assemblies were not installed, because of the size and weight involved, it was not possible to check the ogive transducer and other clamshell associated instrumentation. Payload tests were performed, using the Payload Ground Control Console (see Figure 35) which, originally designed for the Aerobee 350, had been modified to meet Flight 16.02 requirements.

GROUND STATION SUPPORT

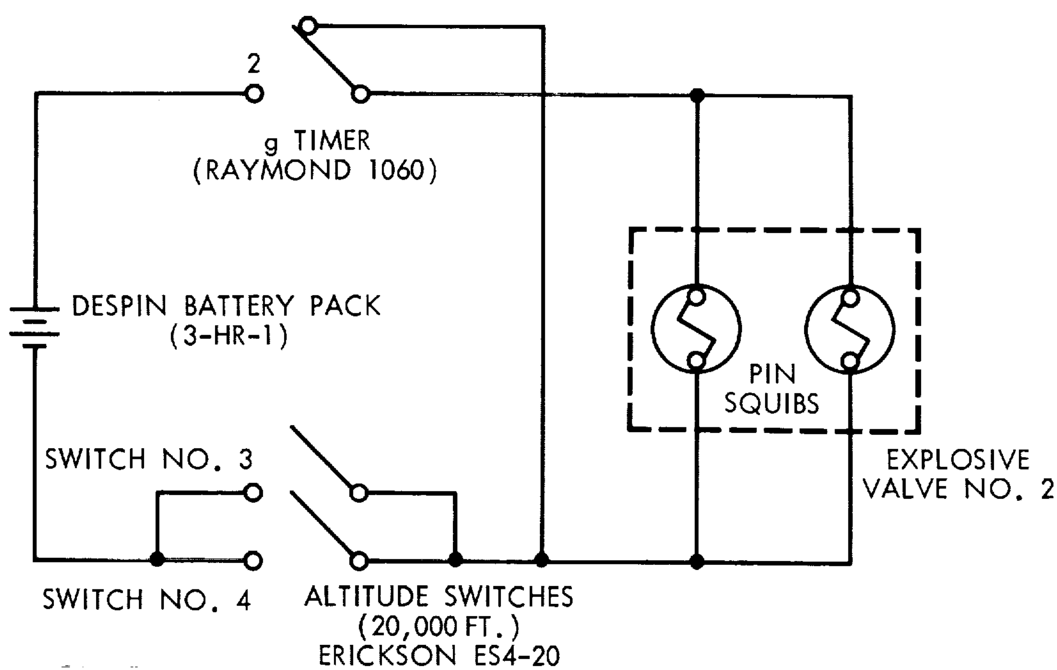
The facilities of six telemetry receiving stations were employed to support Flight 16.02. These were Wallops Main Base Station, GSFC Stations A and H, GSFC Beltsville Station G, NASA Bermuda Station, and the Wallops Downrange Station at Coquina.

WALLOPS MAIN BASE STATION

At Wallops Main Base Station is the telemetry ground station used during the horizontal and vertical preflight checks, and the AN/FPS-16 and Spandar radars used for rocket tracking. Telemetry antennas employed were a high gain General Bronze and two medium gain, all controlled by AGAVE (Automatic



DESPIN OPERATION NO. 1 (12 r/s TO 9 r/s)



DESPIN OPERATION NO. 2 (9 r/s TO 6 r/s)

Figure 34. Yo-Yo Despin Assembly, Schematic Diagram

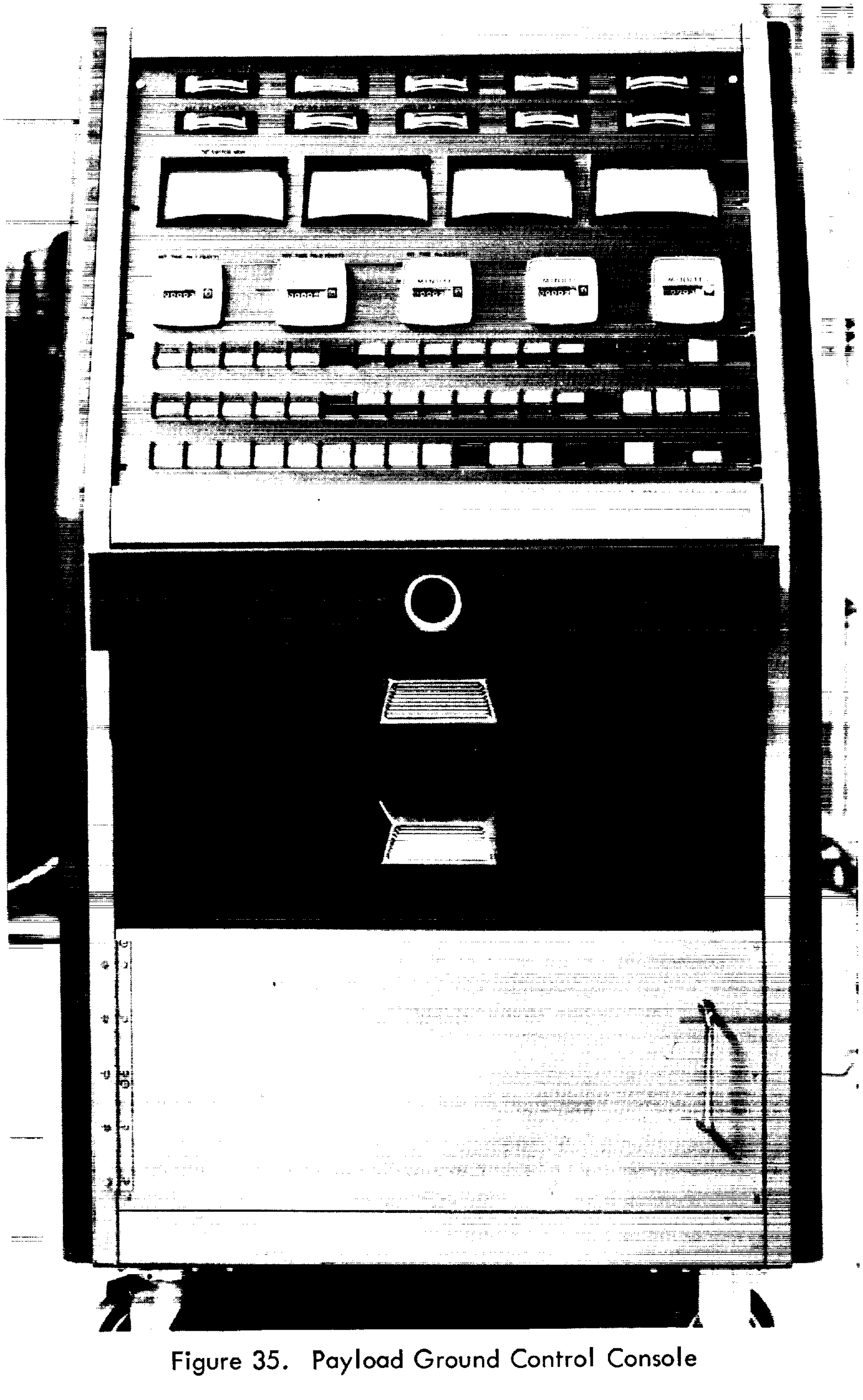


Figure 35. Payload Ground Control Console

Gimbaled Antenna Vectoring Equipment) systems. The high gain antenna is a phase monopulse, right circular polarized, 32-element array, with an overall diameter of 40 feet. Subdivided into quadrants, the array provides four-phase centers symmetrically placed about the boresight axis. Antenna gain was 28 decibels, and frequencies received were 231.4 and 240.2 megahertz.

Of the two medium gain antennas, one is of lefthand and the other is of righthand circular polarization. Both antennas are phase monopulse, four element arrays, and each has a gain of about 18 decibels. These were used to receive the 244.3 and 240.2 megahertz telemetry data. During the flight, the Wallops Main Base Station recorded two seven-track, IRIG standard 1/2-inch magnetic tapes at 60 inches per second. Tape speed compensation was 100 kilohertz with 17 kilohertz servo control. Table 16 contains a listing of magnetic tape channel allocations.

Two CEC Model 5-119 magnetic oscillograph recorders were used to record 231.4 megahertz data. Both recorders were operated at 10 inches per second from T-10 seconds to T+100 seconds, at which time the speeds were reduced to 1 inch per second until impact. Table 17 lists the galvanometer assignments for the two recorders.

Table 16
WALLOPS MAIN BASE STATION, MAGNETIC TAPE TRACKS

TRACK	ALLOCATION
1	Voice
2	Telemetry 1 (240.2 MHz)
3	Telemetry 2 (231.4 MHz)
4	Telemetry 3 (244.3 MHz)
5	Telemetry 1 Backup (240.2 MHz)
6	100 KHz and 17 KHz
7	Range Timing

Table 17
WALLOPS MAIN BASE STATION, OSCILLOGRAPH RECORDER ALLOCATIONS

GALVO NO.	ALLOCATION
RECORDER 1 (231.4 MEGAHERTZ VIDEO)	
1	Range Timing
2	70 KHz (E) Vibration Thrust
3	40 KHz (C) Vibration Pitch
4	22 KHz (A) Vibration Yaw
5	Reference Trace
6	14.5 KHz High Temperature Gauges (Commutated)
7	10.5 KHz Low Temperature Gauges (Commutated)
8	7.35 KHz Voltage Monitor (Commutated)
9	Range Timing
RECORDER 2 (231.4 MEGAHERTZ VIDEO)	
1	Range Timing
2	5.4 KHz Strain Gauge 6
3	3.9 KHz Strain Gauge 5
4	3.0 KHz Strain Gauge 4
5	Reference Trace
6	2.3 KHz Strain Gauge 3
7	1.7 KHz Strain Gauge 2
8	1.3 KHz Strain Gauge 1
9	Range Timing

TELEMETRY STATION A

Station A is a fixed telemetry receiving station located on Wallops Island in Blockhouse 1. Two of the station antennas are of the eight-turn tri-helix kind, with righthand circular polarization. These were used to receive 240.2 and 231.4 megahertz telemetry data. In addition, two eight-turn helix antennas were used to receive 244.3 and 231.4 megahertz backup data. Table 18 lists the data recorded on magnetic tape at Station A. Tape speed was 60 inches per second, with 100 kilohertz compensation, and 17 kilohertz servo control.

Table 18
STATION A, MAGNETIC TAPE TRACKS

TRACK	ALLOCATION
1	Voice and 100 KHz
2	Telemetry 1 (240.2 MHz)
3	Telemetry 2 (231.4 MHz)
4	Telemetry 3 (244.3 MHz)
5	Station Multiplex*
6	Telemetry 2 Backup (231.4 MHz)
7	17 KHz Servo

*Station Multiplex:

70 KHz - 36 Bit Timing	7.35 KHz - AGC (Telemetry 1)
52.5 KHz - 28 Bit Timing	5.4 KHz - AGC (Telemetry 2)
40 KHz - Voice	3.9 KHz - AGC (Telemetry 3)

Two CEC Model 5-119 magnetic oscillograph recorders were used to record 240.2 megahertz data. Both recorders operated at 10 inches per second, from T-10 seconds to T+100 seconds, and then were reduced to 1 inch per second until impact. Table 19 lists the galvanometer assignments for the two recorders.

Table 19
STATION A, OSCILLOGRAPH RECORDER ALLOCATIONS

GALVO NO.	ALLOCATION
RECORDER 1 (240.2 MEGAHERTZ VIDEO)	
1	Range Timing
2	70 KHz Solar Aspect
3	52.5 KHz Chamber Pressure
4	40 KHz Accelerometer (Low Drag)
5	Reference Trace
6	30 KHz Accelerometer (Low Drag)
7	14.5 KHz Accelerometer (Pitch)
8	10.5 KHz Accelerometer (Yaw)
9	Range Timing
RECORDER 2 (240.2 MEGAHERTZ VIDEO)	
1	Range Timing
2	22 KHz Pyrotechnic Events
3	7.35 KHz Roll Gyro
4	5.4 KHz Pitch Gyro
5	Reference Trace
6	3.9 KHz Yaw Gyro
7	3.0 KHz Roll Magnetometer
8	2.3 KHz Thrust Magnetometer
9	Range Timing

TELEMETRY STATION H

Station H, located at Wallops Island adjacent to Blockhouse 1, consists of a 28-foot mobile trailer, housing FM/FM telemetry receiving and recording equipment. Two eight-turn helix antennas were employed to receive the 244.3 megahertz airborne telemetry. Table 20 lists the magnetic tape tracks recorded at Station H. Tape speed was 60 inches per second, with 100 kilohertz compensation and 17 kilohertz servo control.

Table 20
STATION H, MAGNETIC TAPE TRACKS

TRACK	ALLOCATION
1	Voice
2	Receiver 1
3	Receiver 2
4	Spare
5	Spare
6	100 KHz and 17 KHz
7	Range Timing

Real-time permanent paper records were made at Station H, using two CEC Model 5-119 oscillographs. Both recorders operated at 10 inches per second from T-10 seconds to T+100 seconds, at which time the speed was reduced to 1 inch per second until impact. Table 21 lists galvanometer assignments for the two recorders.

TELEMETRY STATION G

Ground Station G is located at the GSFC, Beltsville, Maryland, facility. The antennas include one 18 decibel gain, eight turn tri-helix and two eight turn single-helix antennas. All may be manually adjusted in azimuth and angular elevation. The first was used to receive the 244.3 megahertz telemetry, while each of the single helix antennas received either the 240.2 or the 231.4 megahertz signal. Magnetic tape records, using the same format as Wallops Main Base Station (Table 16), were made by Station G in support of Flight 16.02.

Table 21

STATION H, OSCILLOGRAPH RECORDER ALLOCATIONS

GALVO NO.	ALLOCATION
RECORDER 1 (244.3 MEGAHERTZ VIDEO)	
1	Range Timing
2	70 KHz Chamber Pressure
3	52.5 KHz Vibration, Thrust
4	40 KHz Vibration, Yaw
5	Reference Trace
6	30 KHz Vibration, Clamshell
7	14.5 KHz Ogive (Commutated)
8	Range Timing
RECORDER 2 (244.3 MEGAHERTZ VIDEO)	
1	Range Timing
2	22 KHz Temperature (Commutated)
3	10.5 KHz Clamshell, Pressure
4	7.35 KHz Ogive, Pitch
5	Reference Trace
6	5.4 KHz Clamshell Position, Pitch
7	3.9 KHz Clamshell Position, Yaw
8	Range Timing

NASA BERMUDA STATION

The downrange telemetry ground station at Bermuda has full FM/FM standard IRIG capability. Only the tape recording facilities were used, however, in support of Flight 16.02. During the flight, a seven-track 1/2-inch tape was recorded at 60 inches per second. Tape speed compensation was 100 kilohertz, with 17 kilohertz servo control. Table 22 lists the magnetic tape track assignments for data recorded at this station.

Table 22
NASA BERMUDA STATION, MAGNETIC TAPE TRACKS

TRACK	ALLOCATION
1	Voice
2	Telemetry 1 (240.2 MHz)
3	Telemetry 2 (231.4 MHz)
4	Telemetry 1 (Backup)
5	Telemetry 2 (Backup)
6	100 MHz and 17 MHz
7	Range Timing

COQUINA STATION

The facilities of the GSFC telemetry ground station located at Coquina Beach, North Carolina, were also used to support Flight 16.02. Antennas available at this station include both quad-helix and single-helix having a frequency range from 215 to 260 megahertz. Gain of the quad-helix is 16 to 18 decibels, while that of the single helix is 10 to 12 decibels. A magnetic tape record, using the same format as Bermuda (Table 22), was made at this station in support of the flight.

PRELAUNCH PREPARATIONS

Personnel, payload, and support and maintenance equipment arrived at Wallops Island on 19 September 1964. Equipment was unpacked and payload buildup was started immediately. Instrumentation and flight batteries were also prepared. A total of 60 Yardney DC Silvercel silver-zinc alkaline batteries were required. A set of 20 HR-3 cells were installed in each of the two Stage II battery boxes and a set of 20 HR-1 were installed in the interstage battery box. In addition, a duplicate set was prepared for the various prelaunch checks and as flight spares. All batteries were pre-loaded to stabilize ratings and to remove surface charges. Vehicle despin, ignition, and pyrotechnic batteries were of the sealed nickel-cadmium alkaline kind. In accordance with Wallops range safety regulations, these were installed in a discharged condition, and charged prior to flight.

Prior to vehicle mating, an instrumentation check was conducted to ensure proper operation of flight components. This included telemetry checks and measurements of voltage-standing-wave ratio (VSWR). Checks were performed in Launch Area No. 2 (see Figure 36), so that environmental conditions would approximate those of launch.

Vehicle assembly took place on the following day. The tail structure was assembled to the Stage I motor, and recruit motors were installed and aligned. Motors were canted 9 degrees from the vehicle axis so that their thrust vectors would pass through the vehicle center of gravity. The interstage section was then prepared and checks made of the associated batteries, spin motors, and sequencer unit. The section was secured to Stage I after the Stage I igniter and thrust pressure switch were installed on the motor dome. Payload installation was performed after Stage II was secured to the Interstage. Thermal insulation for the payload was provided by an asbestos blanket placed over the forward end of the Stage II motor. Nose cone and clamshells were then assembled over the payload, and the vehicle was installed on the launcher. Figures 37a, 37b, 37c and 37d show the major steps involved in assembling the Astrobee 1500. (Note that the payload shown in Figure 37b is that of Flight 16.01 GT.)

Interstage and Stage II payload umbilical connections were made (see Table 23), and a horizontal integration performed to check systems operation. Table 24 lists the various operations performed. All instrumentation systems were found to be operational. Paper records and magnetic tapes, at the ground station support facilities, were made as required.

Launch, scheduled for 13 October, and cancelled because of time commitments, was rescheduled for 16 October. Batteries were kept charged and further payload checks performed during the ensuing days. Threatening weather on 16 October then caused postponment of the launch date to 19 October.

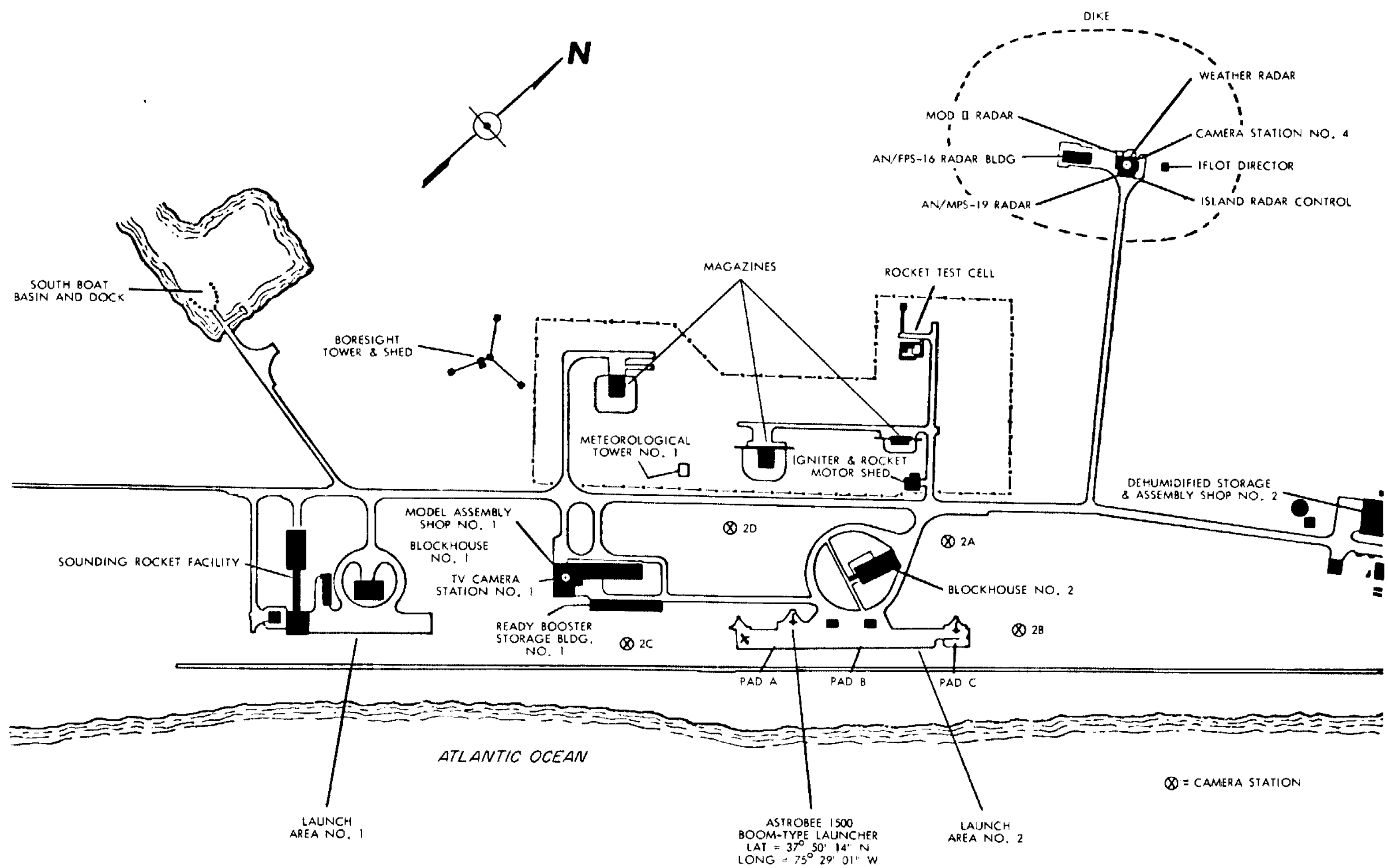
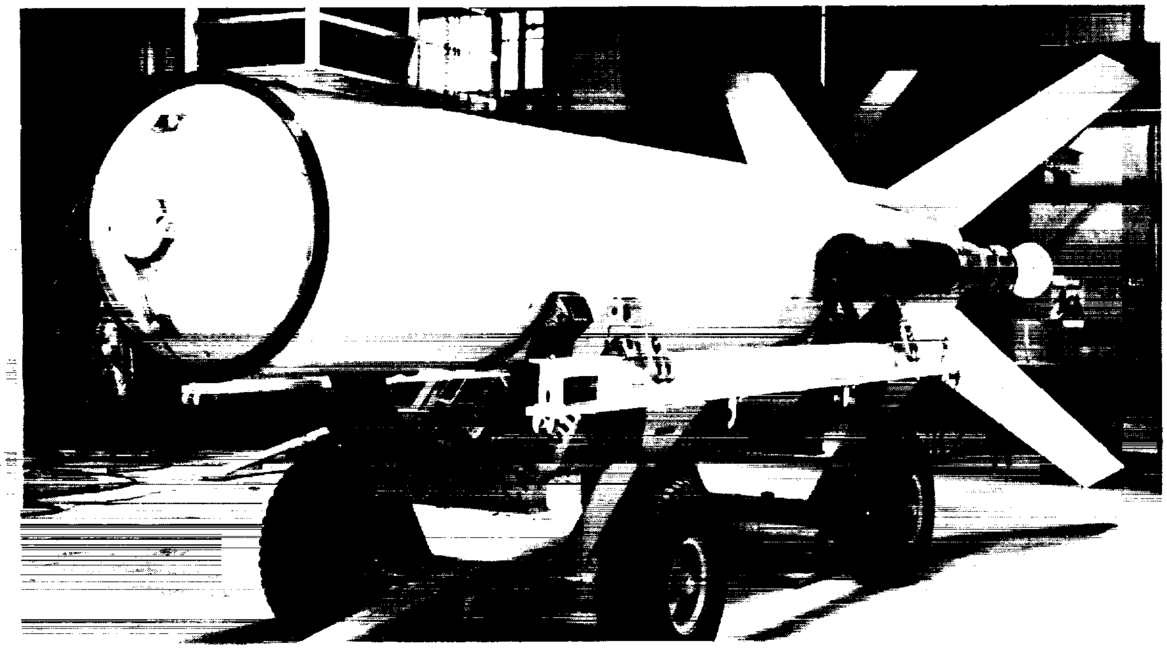
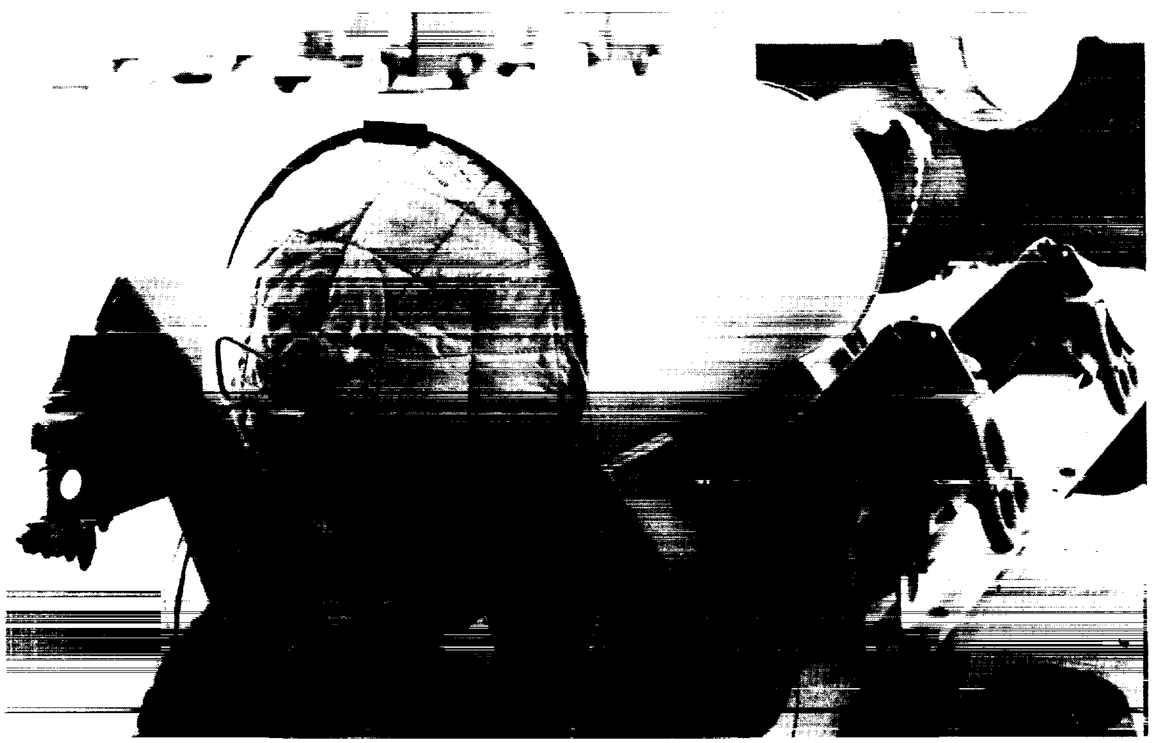


Figure 36. Astrobee 1500 Launch Site at Wallops Island, Virginia

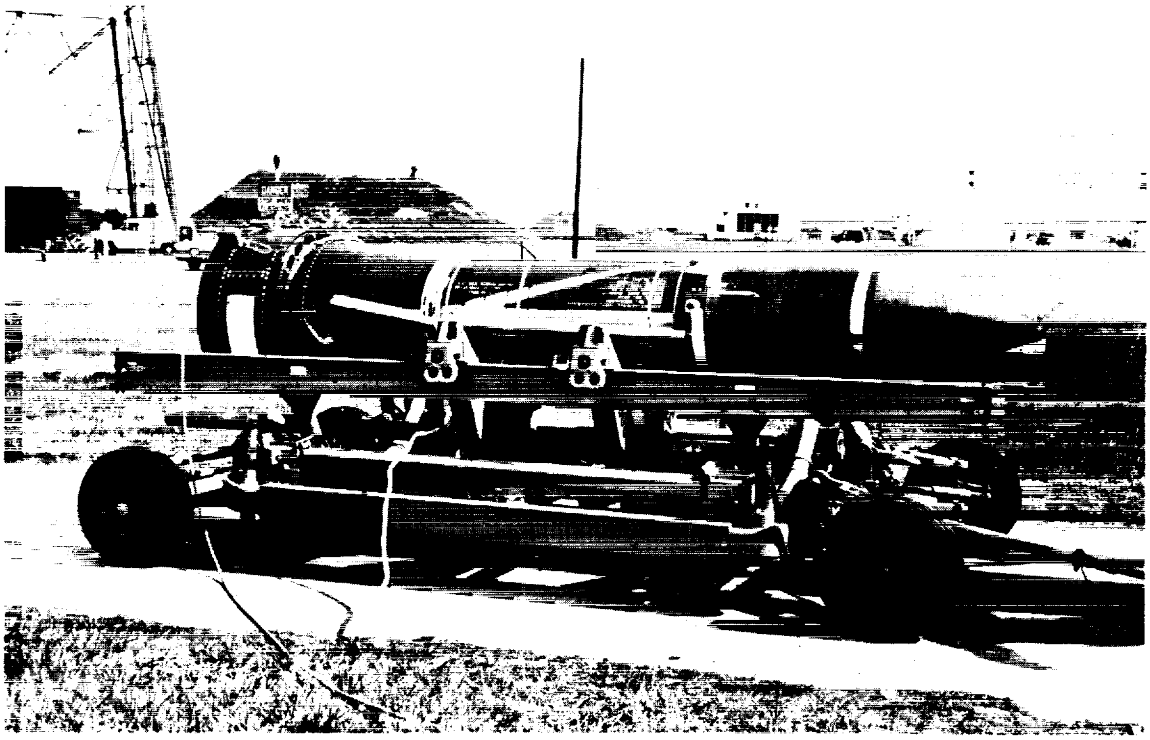


Tail Structure, Fins, and Recruit Motors Attached to Stage I Motor

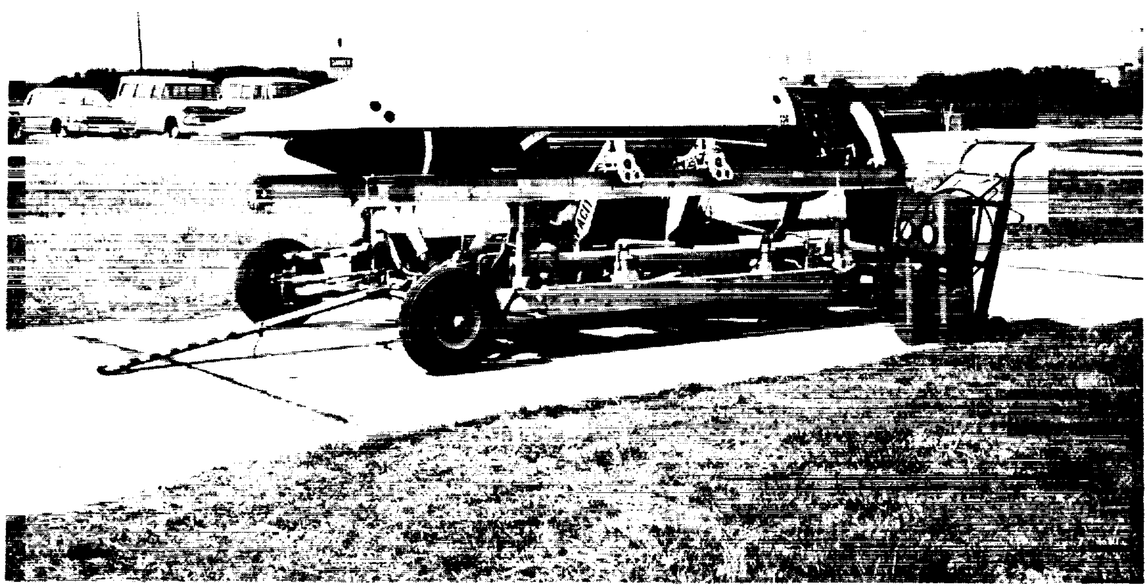


Insulation Blanket Attached to Stage II Motor

Figure 37a. Astrobee 1500 General Assembly and Loading Procedure

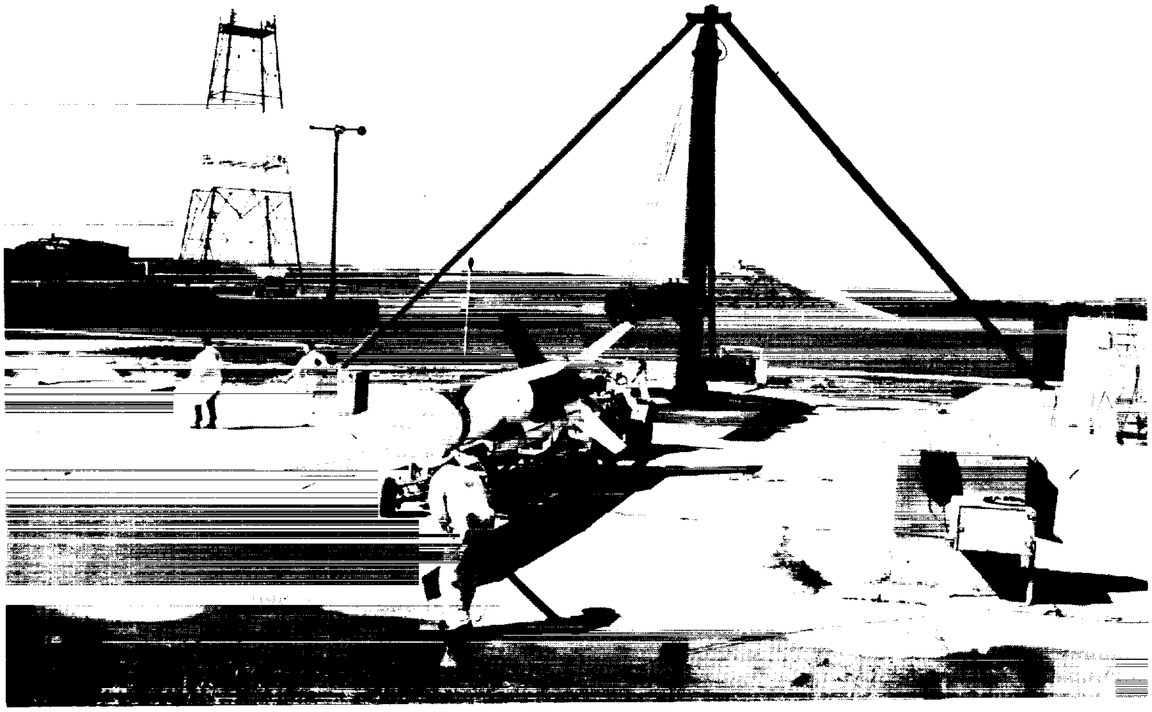


Payload and Nose Cone Assembled to Stage I Motor

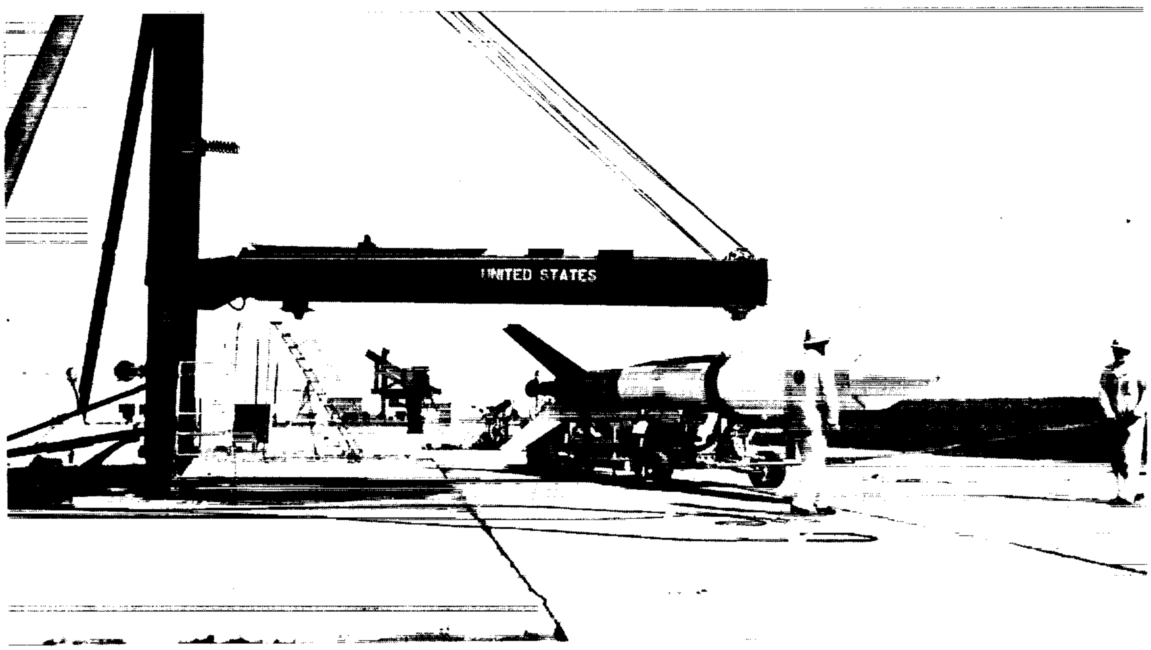


Preliminary Clamshell Installation

Figure 37b. Astrobee 1500, General Assembly and Loading Procedure

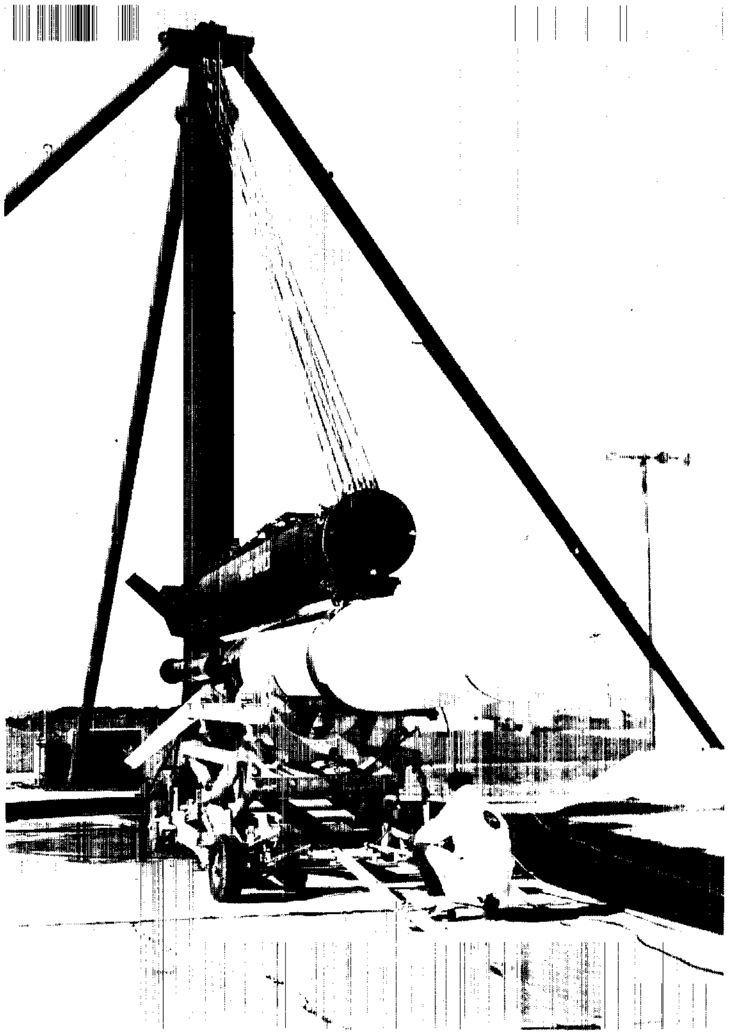


Assembled Vehicle Prior to Launch Installation

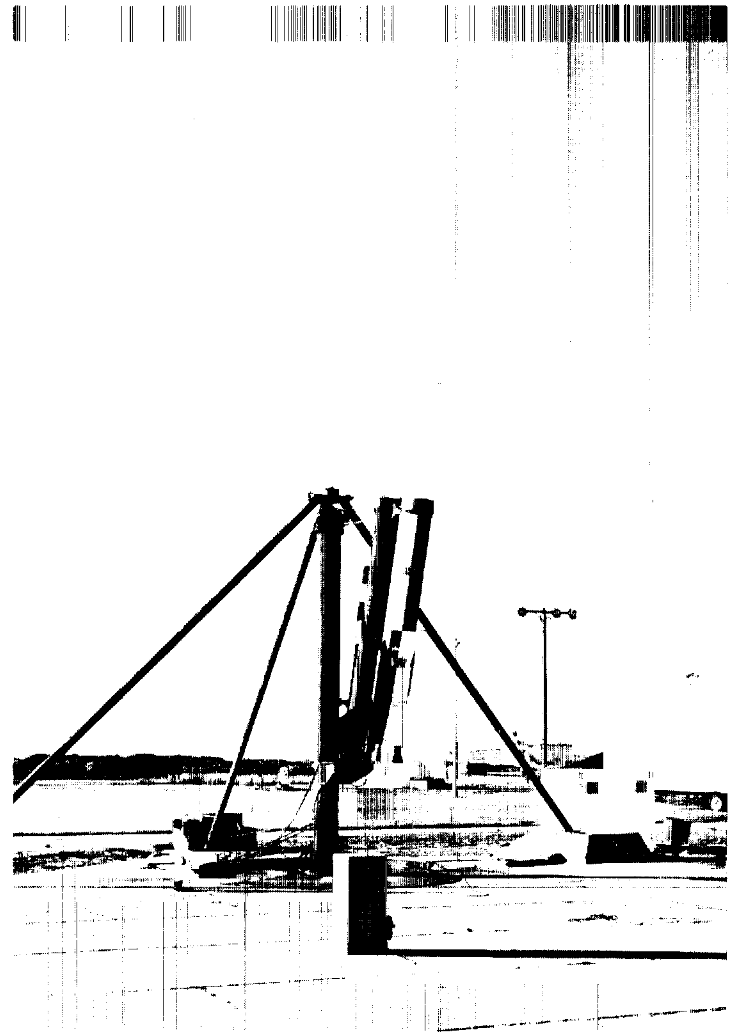


View of Launcher Horizontal Boom

Figure 37c. Astrobee 1500 General Assembly and Loading Procedure



Attachment of Rocket to Launcher



Rocket Elevated to Launching Position

Figure 37d. Astrobee 1500 General Assembly and Loading Procedure

Table 23
PAYLOAD UMBILICAL CABLE CONNECTORS

SECOND STAGE PAYLOAD					
PIN	FUNCTION	PIN	FUNCTION	PIN	FUNCTION
1	Ext. +30 Volts 1	13	P.S. Ground	25	Tx 1 OFF
2	Ext. +30 Volts 1	14	P.S. Ground	26	Tx 2 ON
3	Charge 1	15	Mon. Ground	27	Tx 2 OFF
4	Int. ON 1	16	Uncage Power	28	Cal. 1
5	Int. OFF 1	17	Caging Power	29	Cal. 2
6	Ext. +30 Volts 2	18	Caged signal	30	Comm. ON
7	Ext. +30 Volts 2	19	Uncaged signal	31	Comm. OFF
8	Int. ON 2	20	Gyro ON	32	Inst. Bus. No. 1 VM
9	Int. OFF 2	21	Gyro OFF	33	Inst. Bus. No. 2 VM
10	Charge 2	22	Backup ON	34	Spare
11	Beacon ON	23	Backup OFF	35	Spare
12	Beacon OFF	24	Tx 1 ON		
INTERSTAGE PAYLOAD					
1	Ext. +30 Volts dc	5	Monitor Ground	9	Cal.
2	Ext. +30 Volts dc	6	+30 Volts Monitor	10	Battery Charge
3	Ground	7	Int. ON	11	Spare
4	Ground	8	Int. OFF	12	Spare

Table 24
HORIZONTAL INTEGRATION COUNTDOWN

COUNTDOWN	FUNCTION
T-30 min.	Telemetry ground station ON.
T-25	Instrumentation systems 1, 2, and 3 ON.
T-20	Telemetry systems 1, 2, and 3 ON. Check power supply voltages and currents.
T-12	Stable platform gyro ON. Calibrate telemetry 1, 2, and 3. Check power supply voltages and currents.
T-7	Uncage stable platform gyro.
T-6	Cage stable platform gyro. Tape recorders ON. Paper recorders on slow speed.
T-4	All systems to internal power
T-3	Calibrate telemetry 1, 2, and 3 ON. Confirm at ground station.
T-1	Check instrumentation voltages 1, 2, and 3.
T-10 sec.	Uncage stable platform gyro.
T-5	Paper recorders on fast speed.
T-0	Pullaway plugs OUT.
T+3 sec.	Tap vibration transducers and confirm response.
T+15	Perform longitudinal magnetometer test with magnet moved along thrust axis for 10 seconds.

Table 24 (Continued)
HORIZONTAL INTEGRATION COUNTDOWN

COUNTDOWN	FUNCTION
T+25	Stop longitudinal magnetometer test. Perform roll magnetometer test with magnet moved around payload for 10 seconds.
T+35 sec.	Stop roll magnetometer test. Perform solar aspect test with test fixture slowly rotated and sun gun on sensor for 10 seconds.
T+45	Stop solar aspect test. Paper recorder to slow speed. Start ogive test by moving vanes from center position towards Fin 1 and holding for 10 seconds.
T+55	Return vanes to center position and hold for 5 seconds.
T+60	Move vanes toward Fin 3 and hold for 10 seconds.
T+70	Return vanes to center position and hold for 5 seconds.
T+75	Move vanes toward Fin 2 and hold for 10 seconds.
T+85	Return vanes to center position.
T+90	Move vanes toward Fin 4 and hold for 10 seconds.
T+95	Recorders to fast speed.
T+100	Return vanes to center position. End of ogive test.
T+103	Start stable platform gyro and perform accelerometer 1g test. Roll vehicle 360 degrees in 40 seconds.
T+110	Move front of vehicle down and hold for 10 seconds.

Table 24 (Continued)
HORIZONTAL INTEGRATION COUNTDOWN

COUNTDOWN	FUNCTION
T+120	Move vehicle to horizontal position and hold for 10 seconds.
T+130	Alternately move front of vehicle up and toward left and right for 10 seconds each, after 5 seconds in horizontal position.
T+175 sec.	Pullaway plug IN. Recorders OFF.
T+180	Payload to external power. Cage gyro and all power OFF.

On 19 October at 1700Z hours, vehicle umbilical cables were reconnected and the igniter and explosive bolt squib continuity tests performed. Interstage blowout doors were fastened, and using the electrical system checkout unit (Figure 38), vehicle electrical system checkout tests were performed (refer to Appendix C). Figure 39 contains the Flight 16.02GT rocket launch simplified block diagram.

While final vehicle and payload preparations were performed, various Wallops range personnel commenced support activities preliminary to launch (refer to Appendix D). At 1900Z hours the rocket was elevated to firing position and the payload vertical integration countdown (see Table 25) was performed.

LAUNCH DATA

Astrobee 1500, Flight 16.02, was successfully launched from Wallops Island, Virginia, on 21 October 1964 at 1944Z hours. Launcher settings were 80.0 degrees from true north in azimuth, and 76.5 degrees in elevation. Effective angles were 100.9 degrees and 80.3 degrees, respectively. Based on Doppler radar and tentative plot board data, the vehicle achieved a peak altitude of 1950 kilometers in 846 seconds. Stage II ignition occurred at T+47.5 seconds at an altitude of 165,238 feet. Vehicle velocity at the moment of ignition was 5900 feet per second. Flight duration was 1672 seconds, with impact at a range of 1469.26 kilometers.

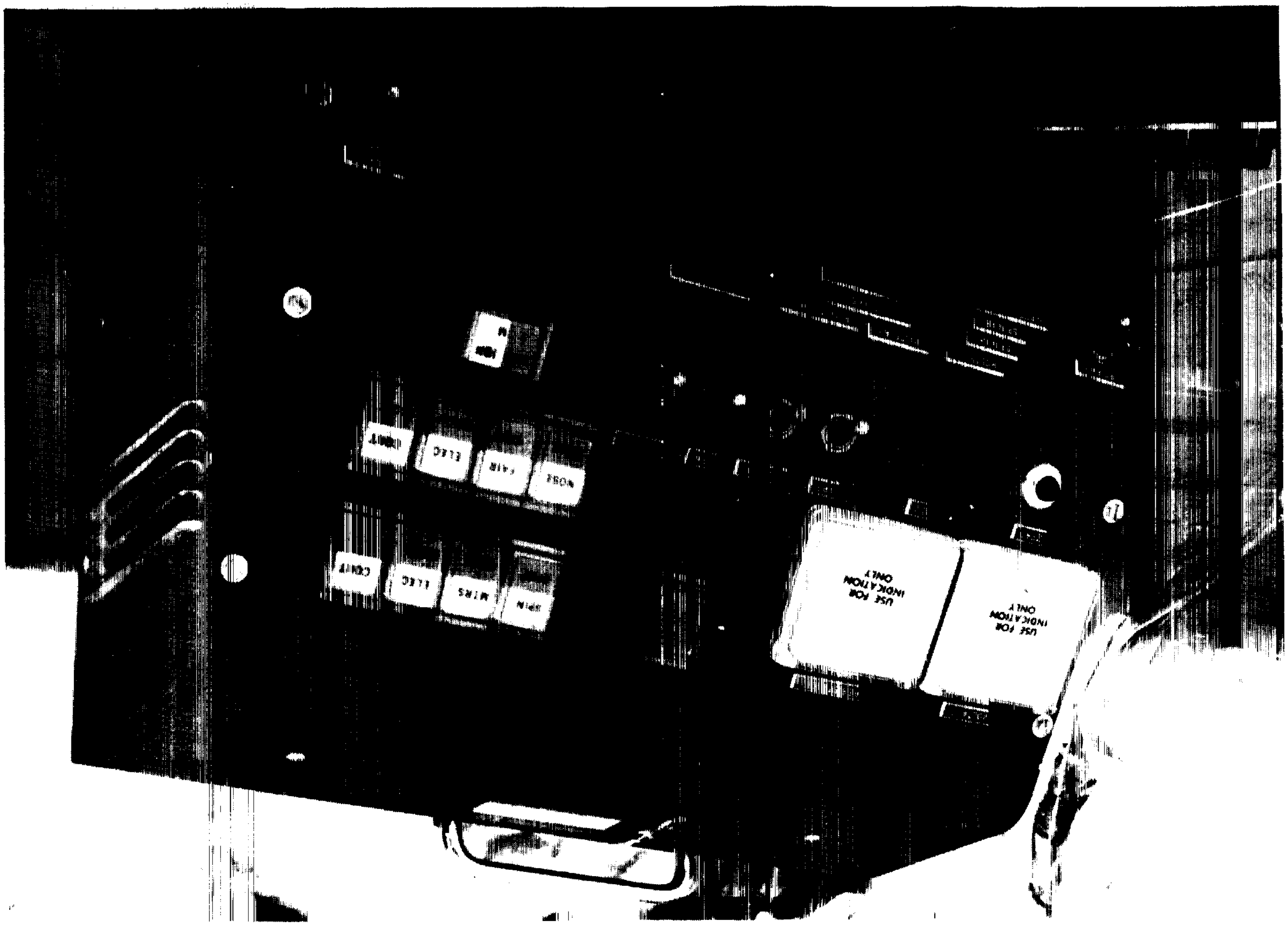
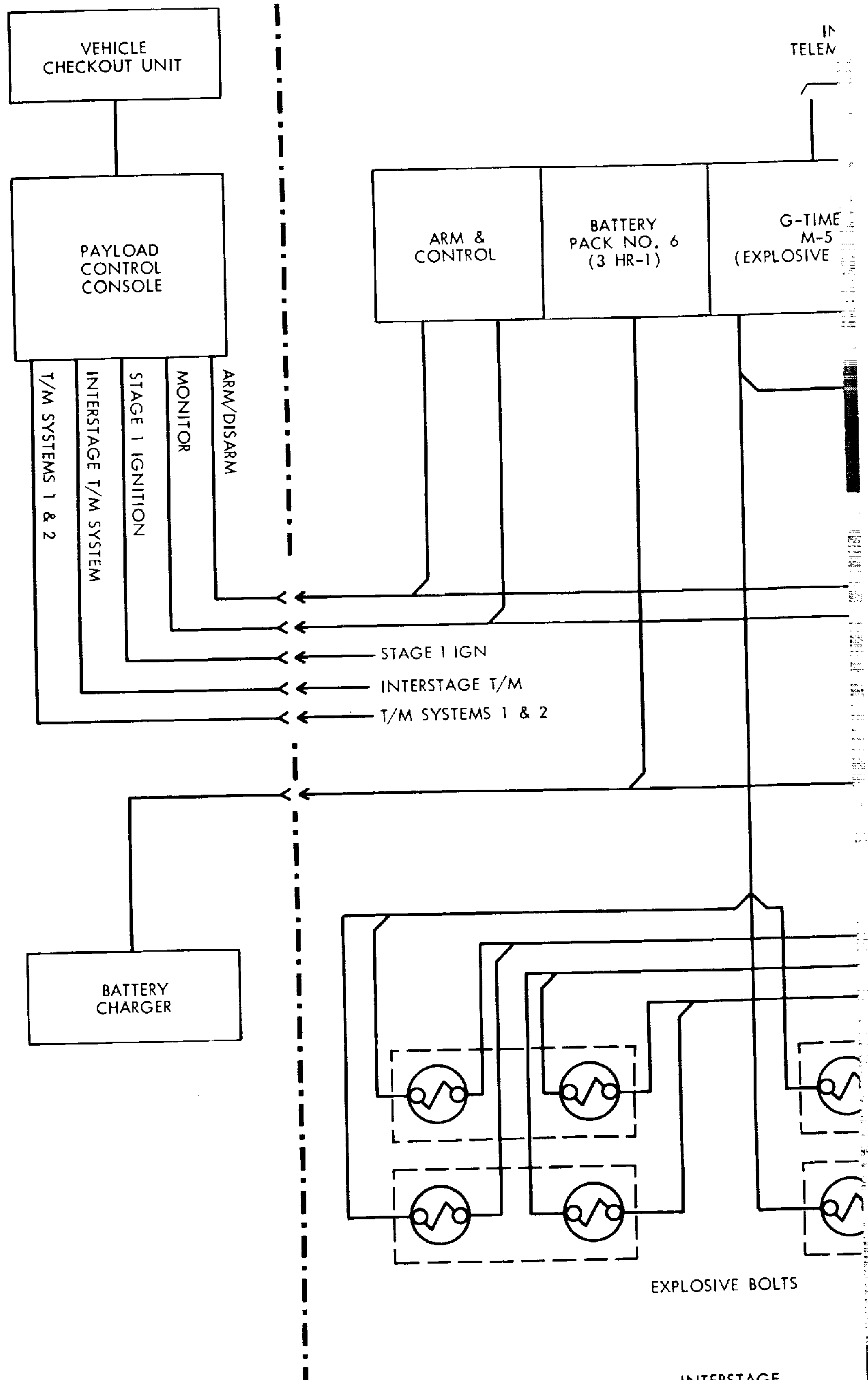


Figure 38. Electrical System Checkout Unit



FOLDOUT FRAME 1

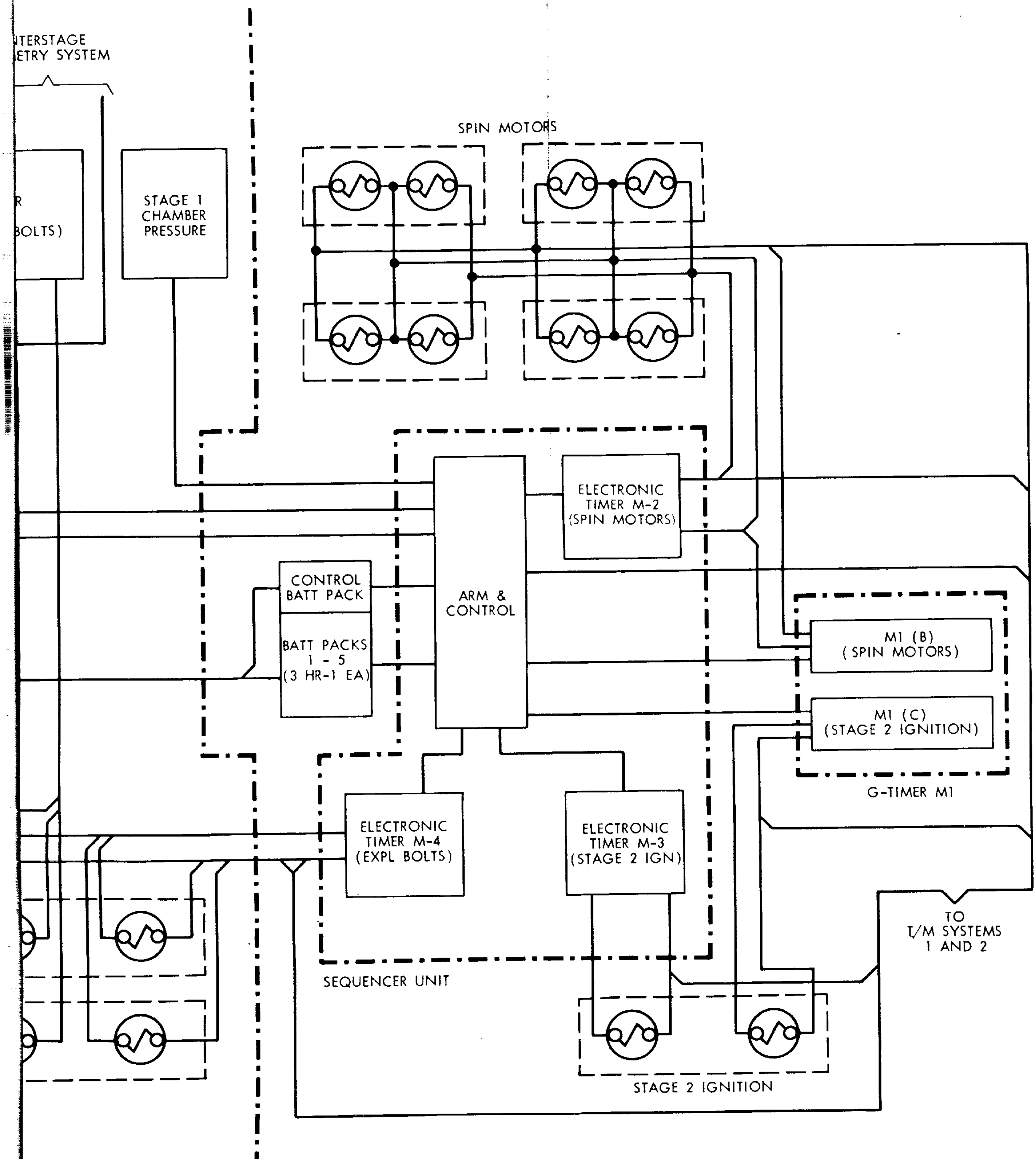


Figure 39. Rocket Launch, Simplified Block Diagram

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Table 25
VERTICAL INTEGRATION COUNTDOWN

COUNTDOWN	FUNCTION
T-20 min.	Instrumentation systems 1, 2, and 3 ON.
T-17	Commutators and stable platform gyro ON.
T-16	Radar beacon ON.
T-15	Telemetry systems 1, 2, and 3 ON.
T-10	Uncage stable platform gyro.
T-8	Cage stable platform gyro.
T-6	Internal power to all systems.
T-5.5	Calibrate.
T-5	Record voltage monitors.
T-4	Backup ON.
T-3	Confirm radar interrogation.
T-2	Calibrate.
T-1	Tape recorders ON.
T-45 sec.	Record voltage monitors.
T-25	Paper recorders ON.
T-20	Uncage stable platform gyro. Confirm sequencer unit armed.
T-6	Calibrate Stage II.
T-0	Ignition.

CONCLUSIONS

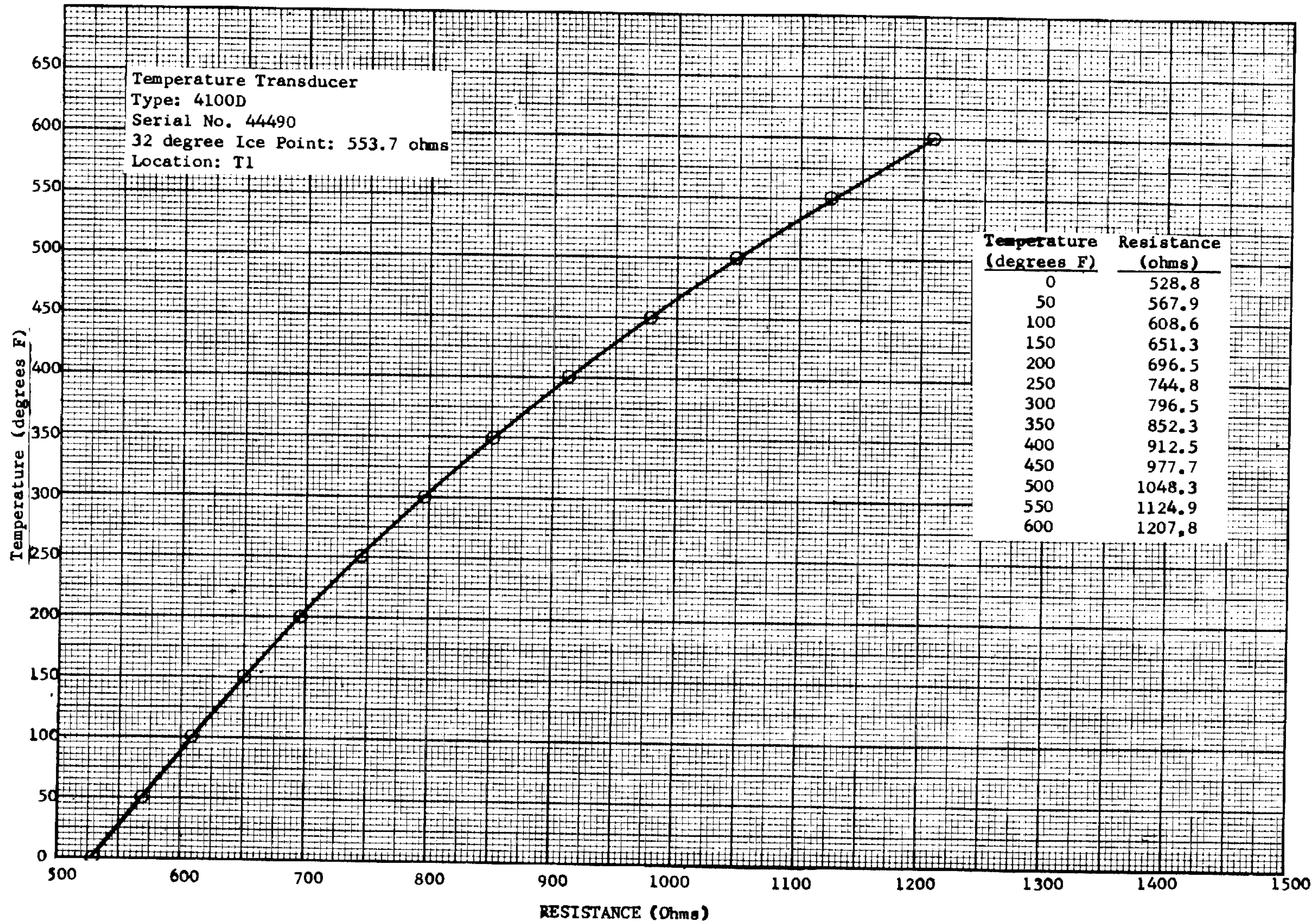
Telemetry data indicated failure of Stage II to achieve the planned 12.5 revolutions per second spin rate, probably because of a malfunction in one of the spin motors. The attained 8.5 revolutions per second rate, however, was sufficient to maintain vehicle stability. A major flight abnormality was the premature release, and loss, of the clamshells at T+38.2 seconds. Preliminary studies suggest that this was probably caused by failure of the securing Marman bands. Re-design or modifications in this area are indicated before proceeding with further Astrobee 1500 flights.

Vehicle performance was about 11 percent below that predicted, mainly because of a second-stage motor modification which resulted in a decrease in propellant weight. Instrumentation performance, pending final data analysis, was excellent. Data from the 244.3 megahertz interstage telemetry system were received for 50 seconds (as expected), with no dropouts, and telemetry from the 240.2 and 231.4 megahertz Stage II telemetry systems was recorded at Wallops Main Base Station for 26 minutes 43 seconds with negligible dropout.

APPENDIX A

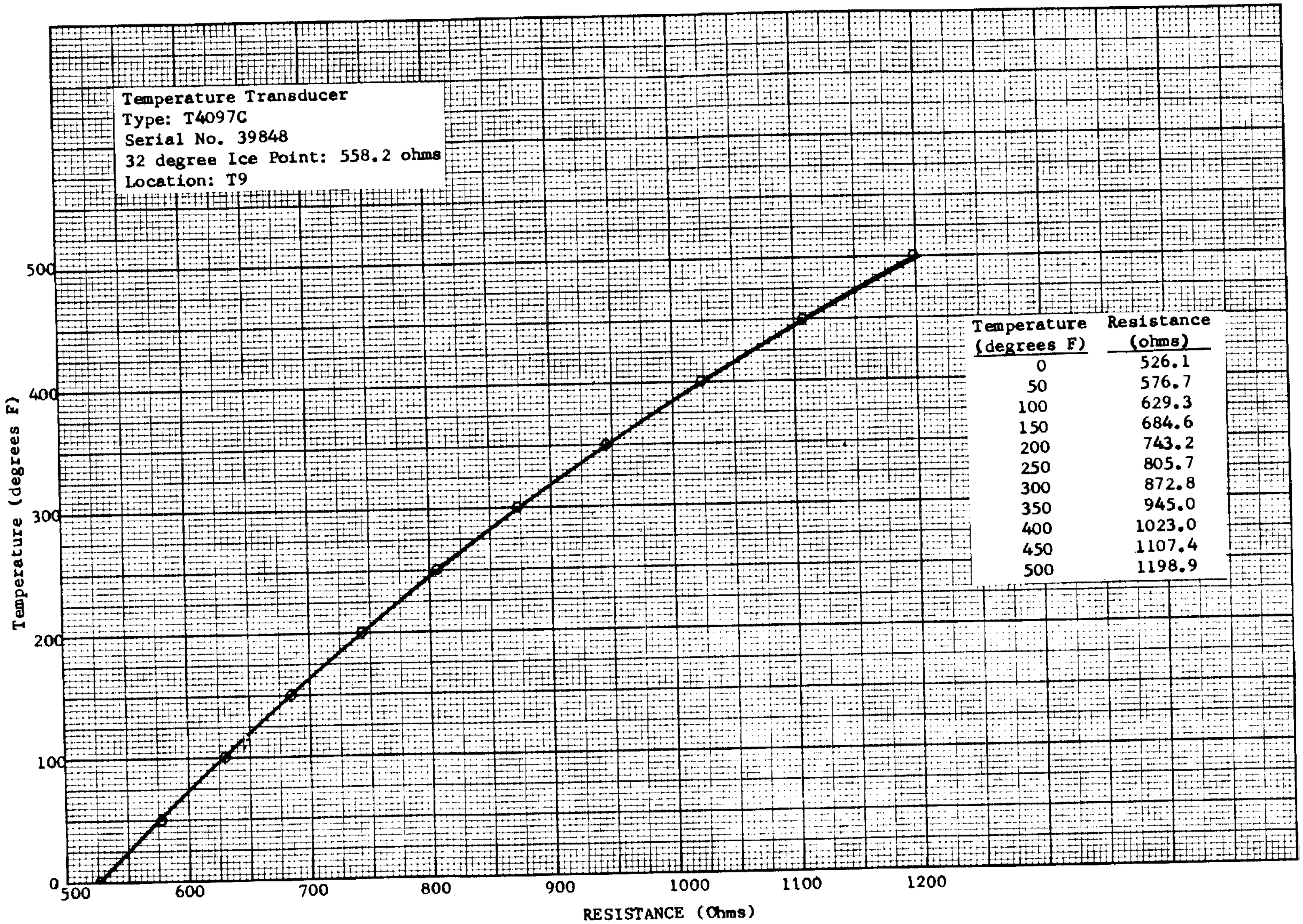
REPRESENTATIVE CALIBRATION DATA AND CURVES

Appendix A contains calibration data and curves for various instruments flown on Astrobee 1500 Flight 16.02 GT. Because of space limitations, only a representative sample has been included. For complete data refer to Compilation of Calibration Curves for Astrobee 1500 Flight 16.02 GT, X-721-67-200.



Temperature (degrees F)	Resistance (ohms)
0	528.8
50	567.9
100	608.6
150	651.3
200	696.5
250	744.8
300	796.5
350	852.3
400	912.5
450	977.7
500	1048.3
550	1124.9
600	1207.8

Figure A-1. Temperature Transducer, Type 4100D, Calibration Curve



Temperature (degrees F)	Resistance (ohms)
0	526.1
50	576.7
100	629.3
150	684.6
200	743.2
250	805.7
300	872.8
350	945.0
400	1023.0
450	1107.4
500	1198.9

Figure A-2. Temperature Transducer, Type 4097C, Calibration Curve

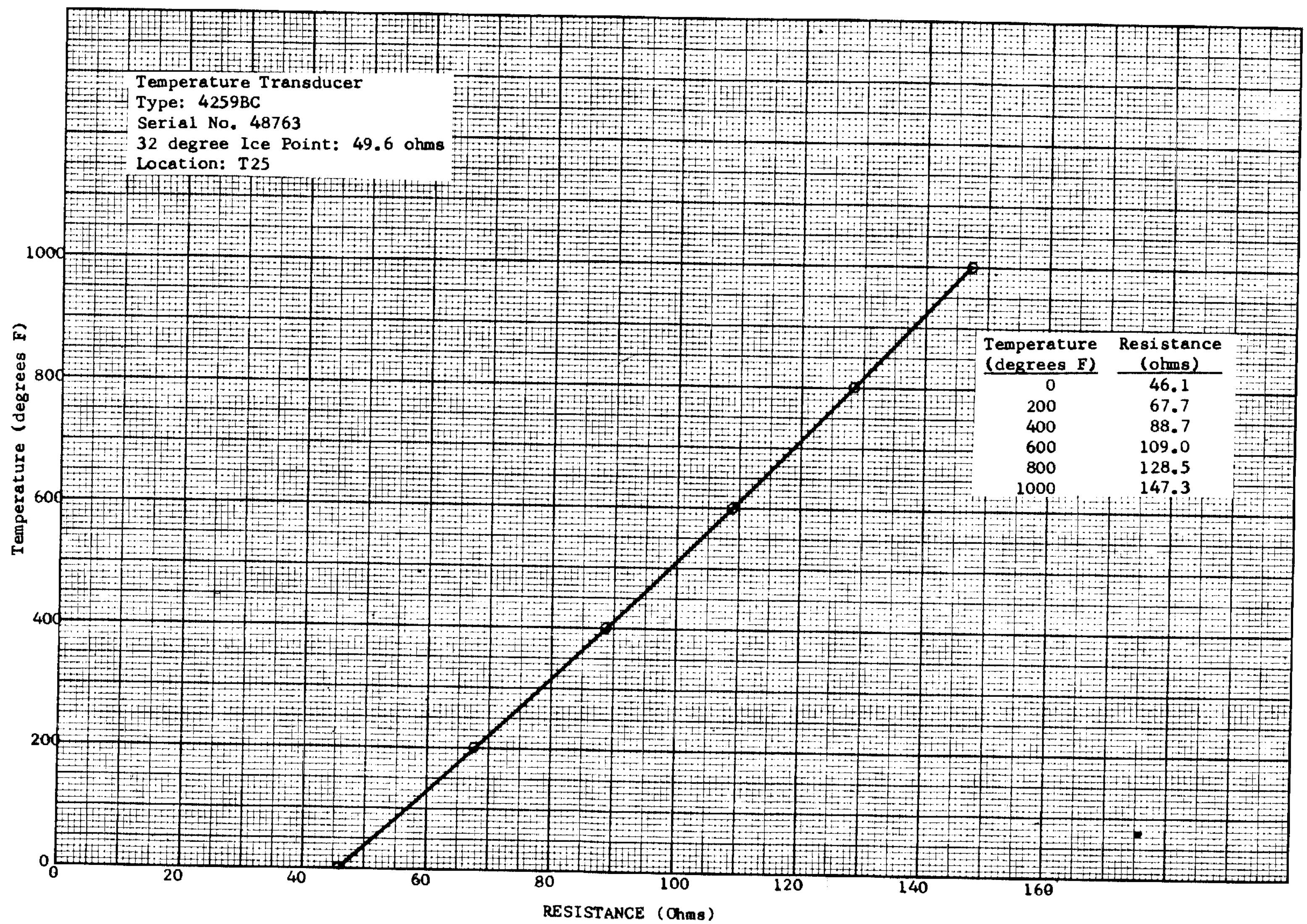


Figure A-3. Temperature Transducer, Type 4259BC, Calibration Curve

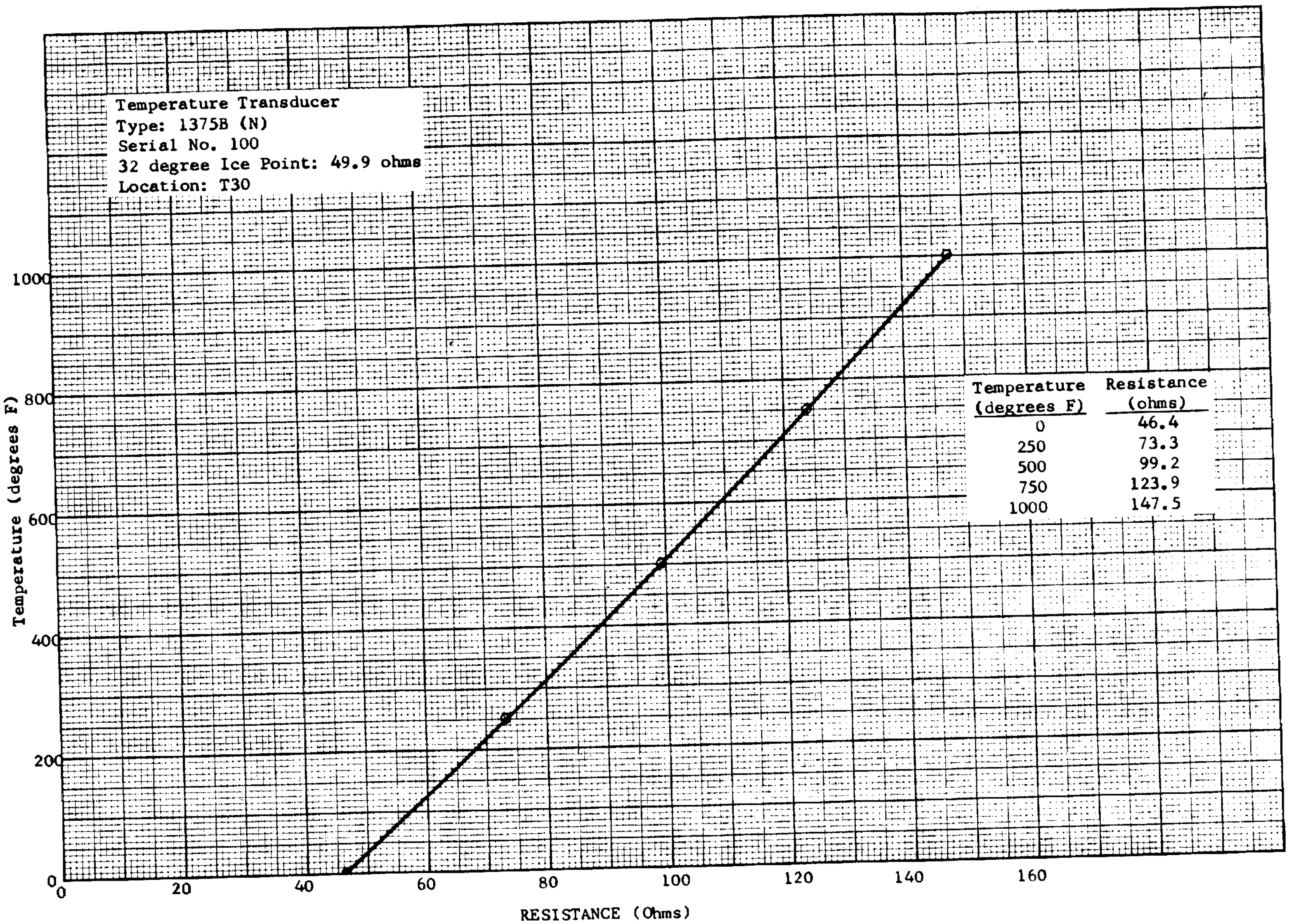


Figure A-4. Temperature Transducer, Type 1375B(N), Calibration Curve

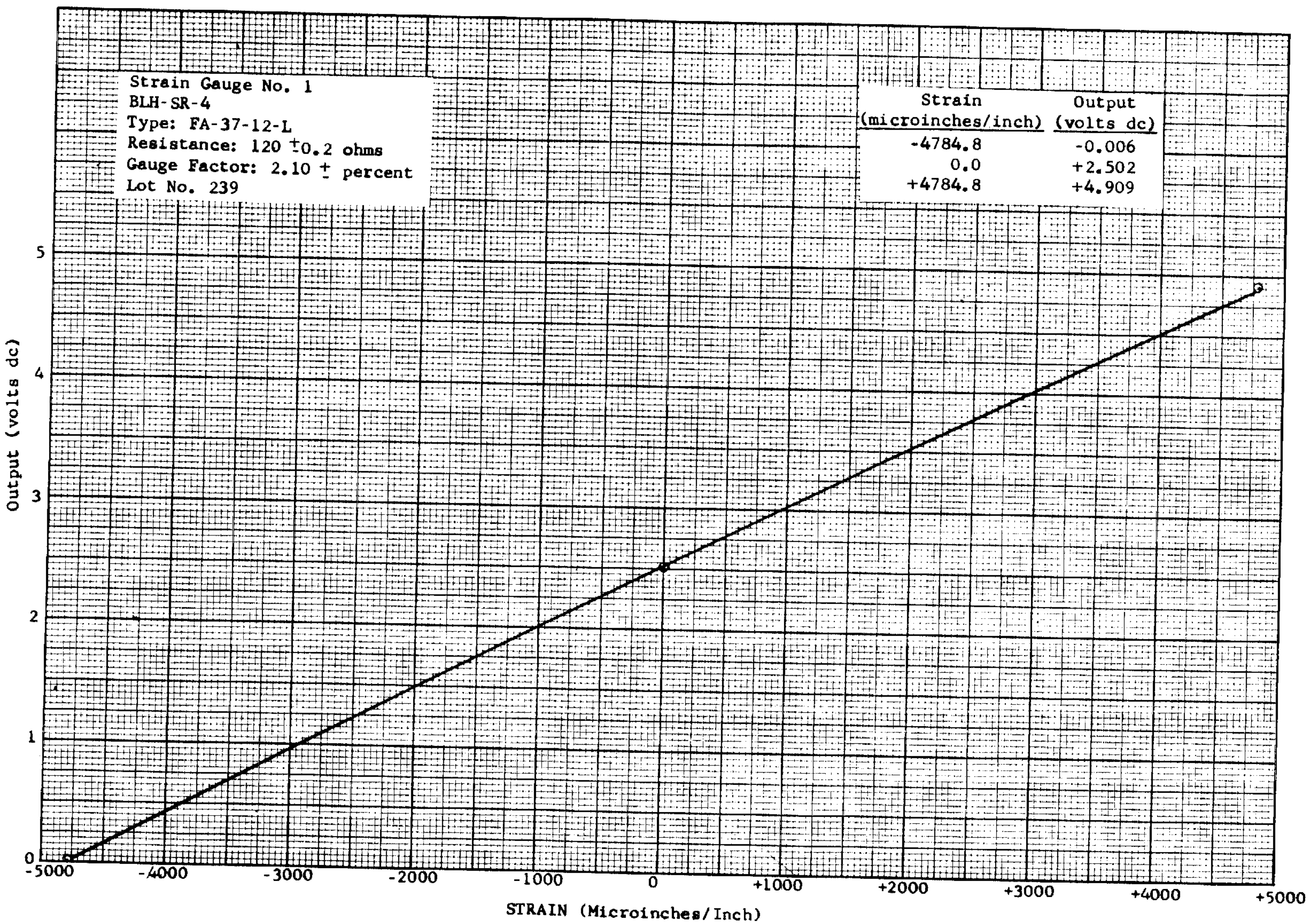
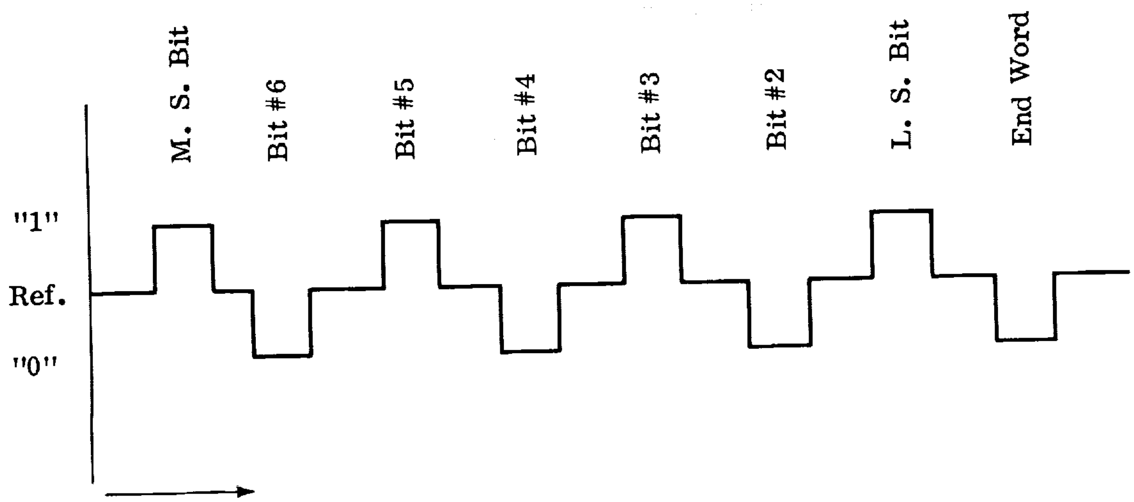


Figure A-5. Strain Gauge, Type FA-37-12-L, Calibration Curve



EOTM - Output Definition

Bit Rate - Determined by C_x

LEVEL DEFINITIONS

Level	Earth Telescope Illuminated (Volts dc)	Earth Telescope not Illuminated (Volts dc)
"1" Level	2.25 ±0.1	4.9 ±0.1
Ref. Level	1.25 ±0.1	3.9 ±0.1
"0" Level	0.25 ±0.1	2.9 ±0.1

Figure A-6. Solar Aspect Sensor, Bit Train Data

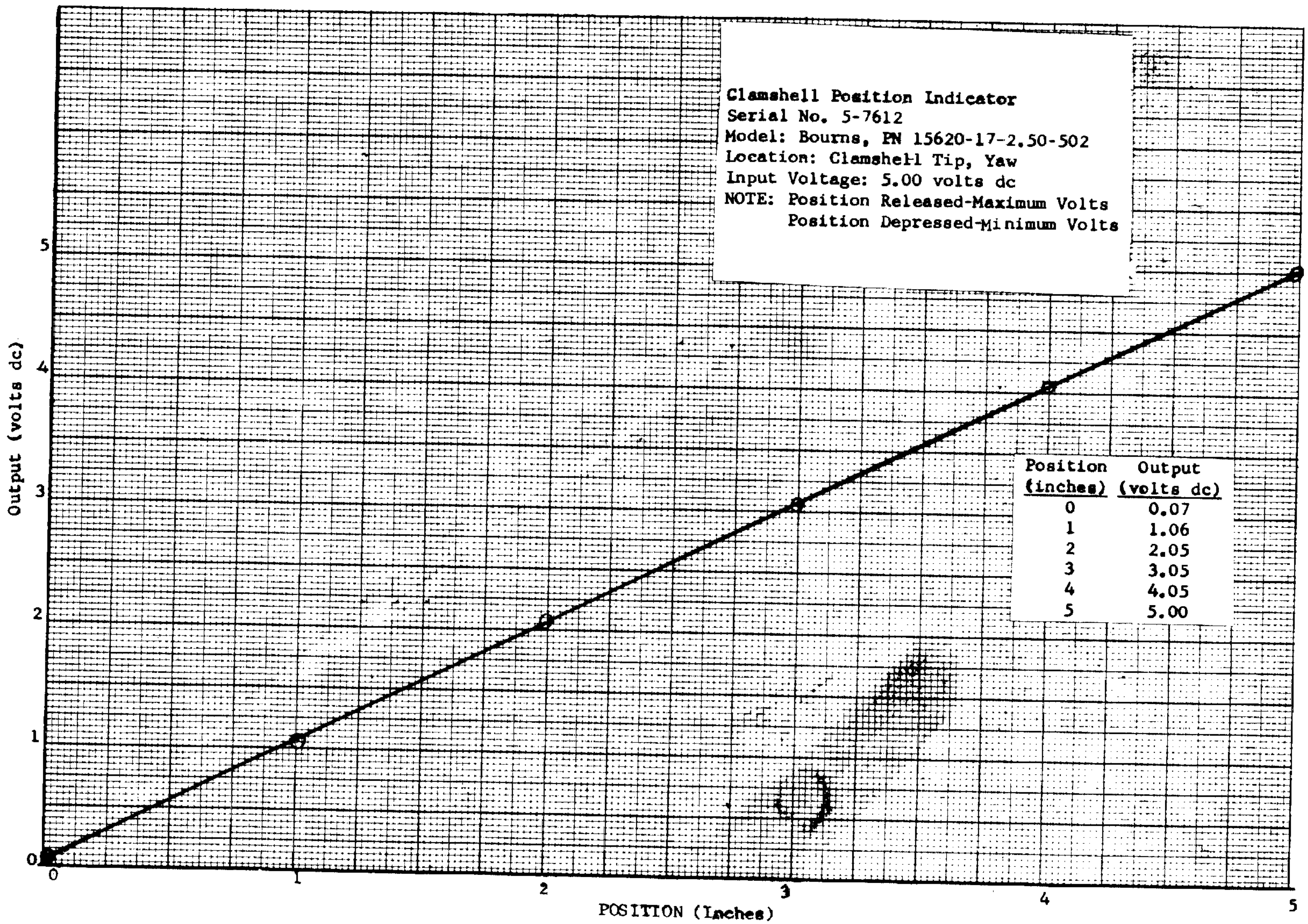
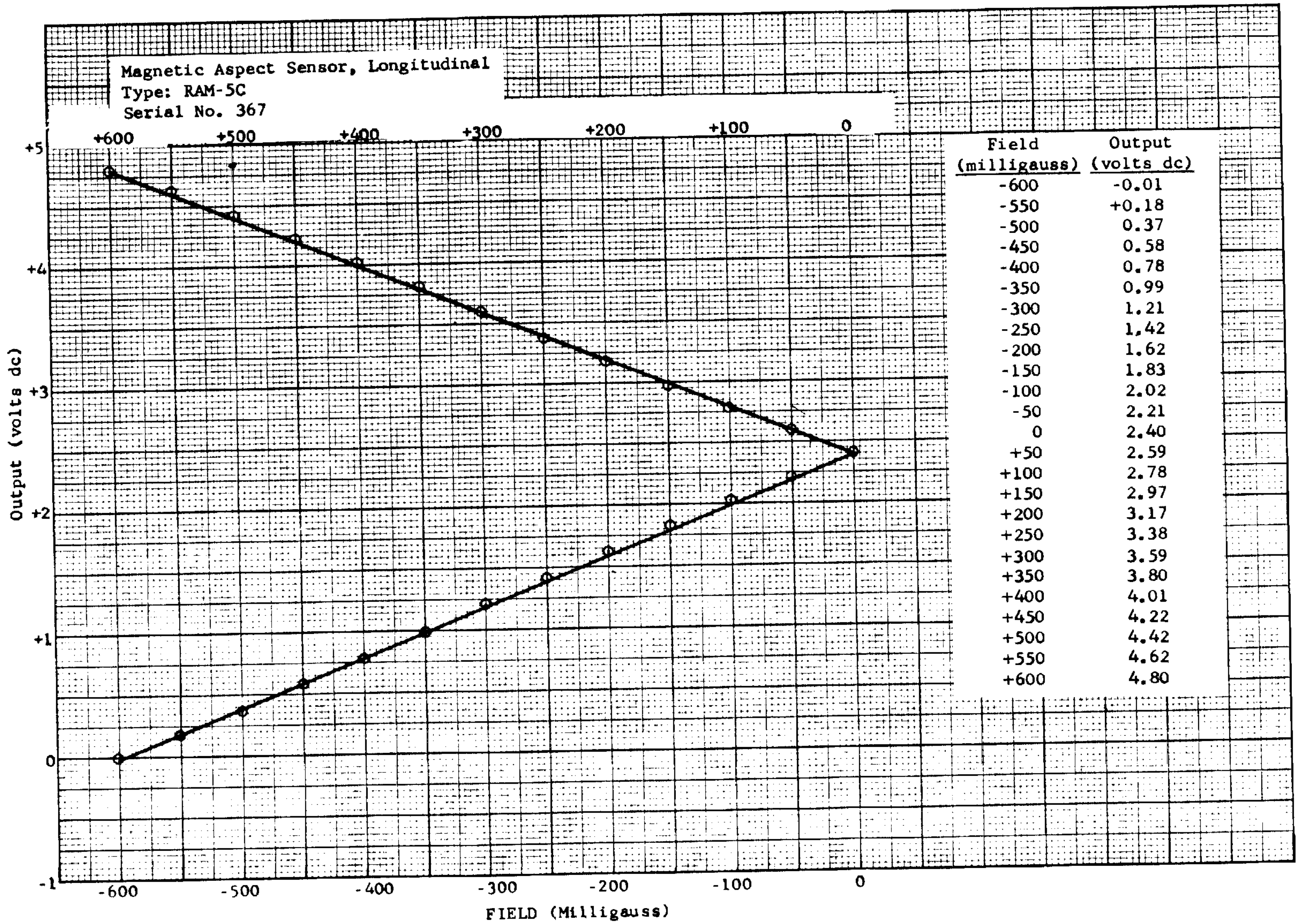
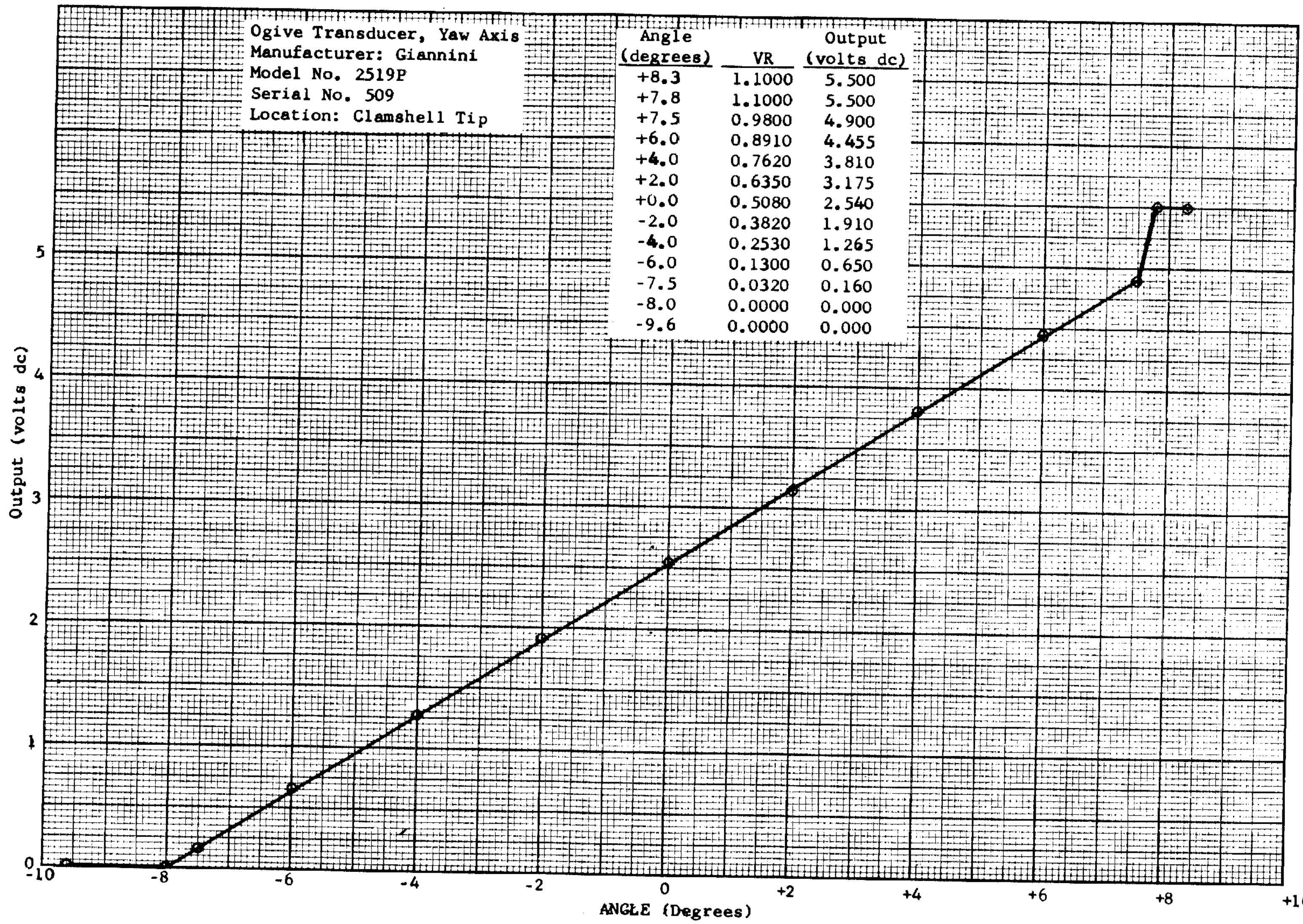


Figure A-7. Clamshell Position Indicator (Yaw), Calibration Curve



Field (milligauss)	Output (volts dc)
-600	-0.01
-550	+0.18
-500	0.37
-450	0.58
-400	0.78
-350	0.99
-300	1.21
-250	1,42
-200	1.62
-150	1.83
-100	2.02
-50	2.21
0	2.40
+50	2.59
+100	2.78
+150	2.97
+200	3.17
+250	3.38
+300	3.59
+350	3.80
+400	4.01
+450	4.22
+500	4.42
+550	4.62
+600	4.80

Figure A-8. Magnetic Aspect Sensor, Type RAM-5C (Longitudinal), Calibration Curve



Angle (degrees)	VR	Output (volts dc)
+8.3	1.1000	5.500
+7.8	1.1000	5.500
+7.5	0.9800	4.900
+6.0	0.8910	4.455
+4.0	0.7620	3.810
+2.0	0.6350	3.175
+0.0	0.5080	2.540
-2.0	0.3820	1.910
-4.0	0.2530	1.265
-6.0	0.1300	0.650
-7.5	0.0320	0.160
-8.0	0.0000	0.000
-9.6	0.0000	0.000

Figure A-9. Ogive Transducer, Type 2519P (Yaw), Calibration Curve

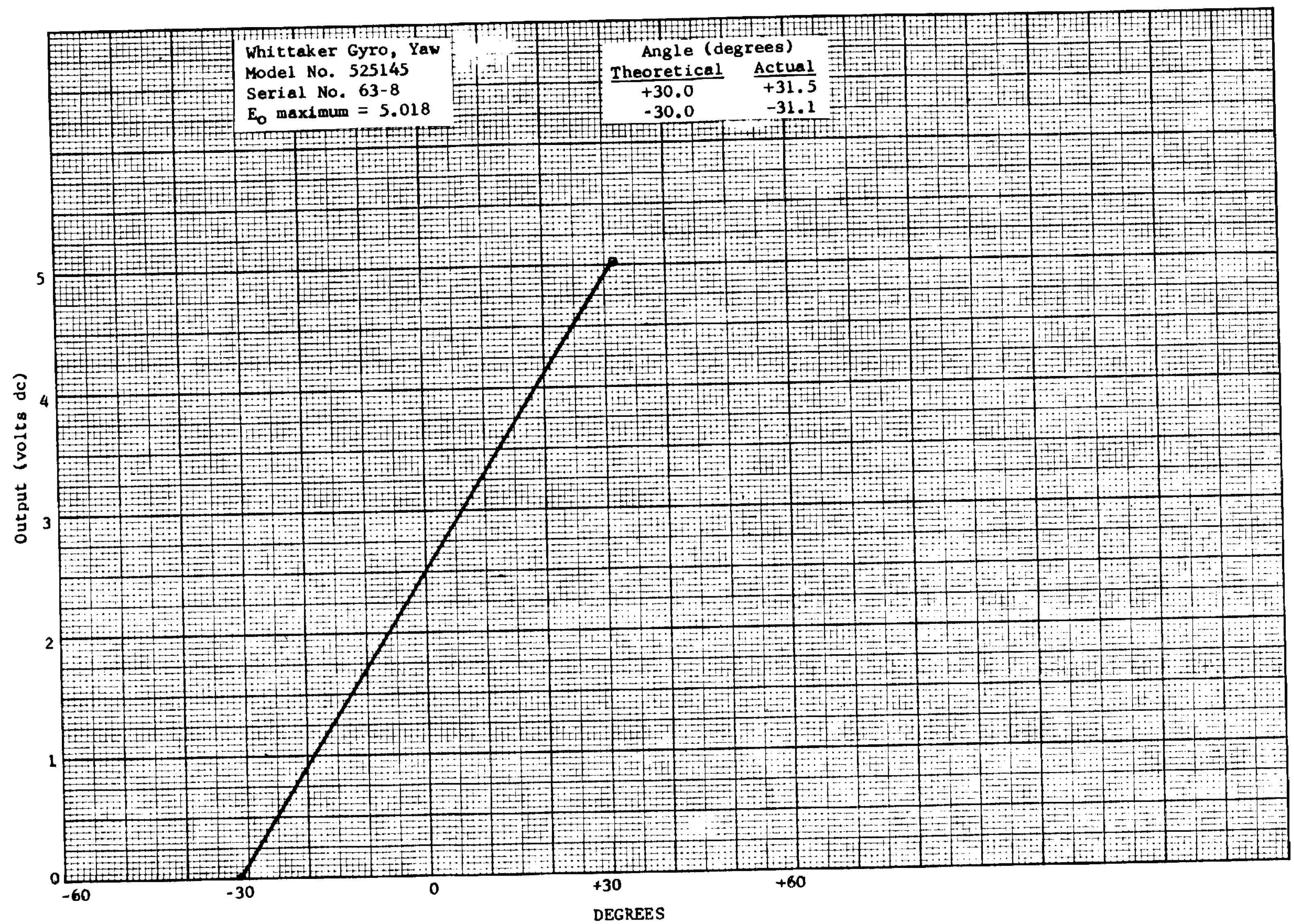


Figure A-10. Stable Platform, Type 525145 (Yaw), Calibration Curve

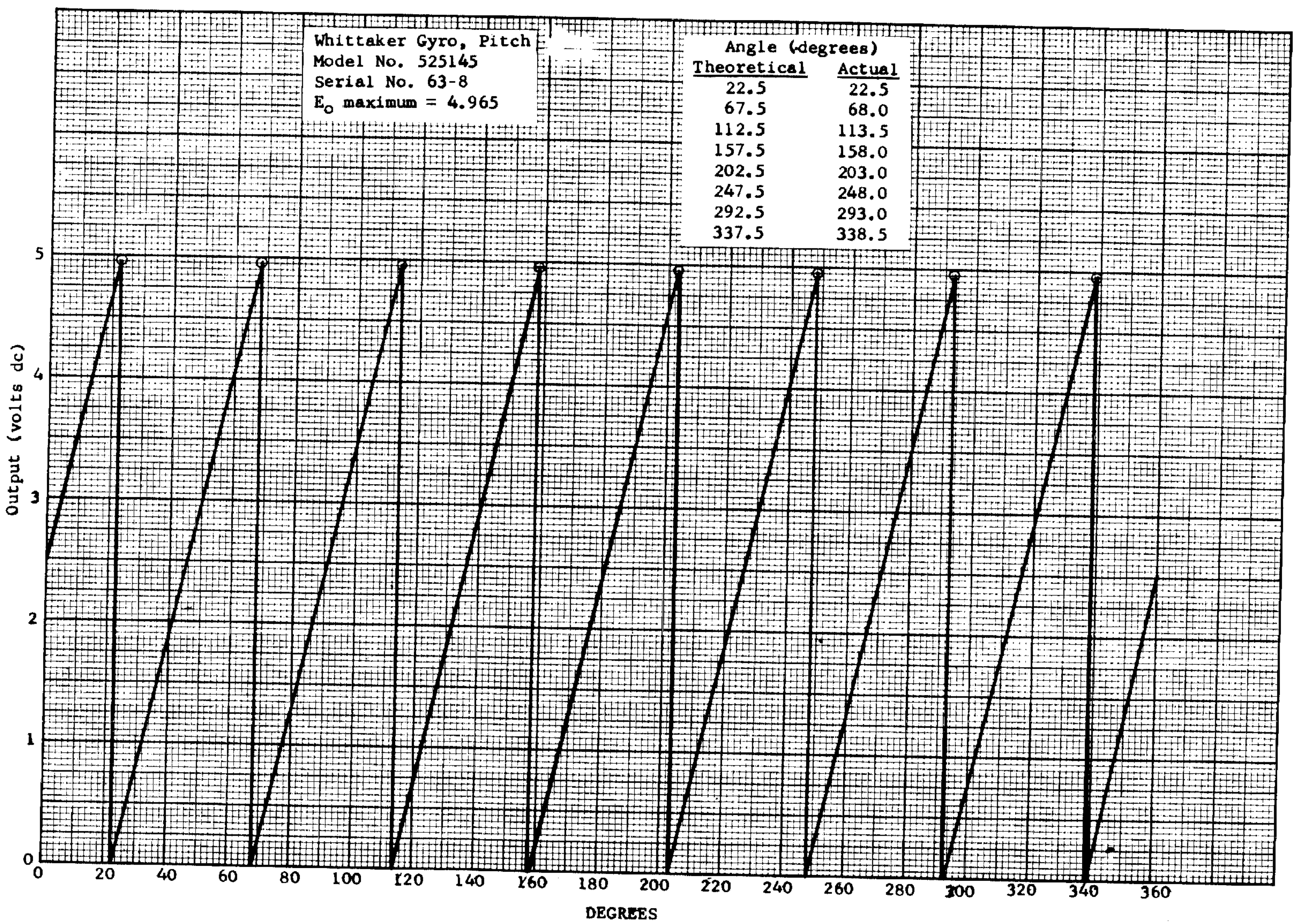


Figure A-11. Stable Platform, Type 525145 (Pitch), Calibration Curve

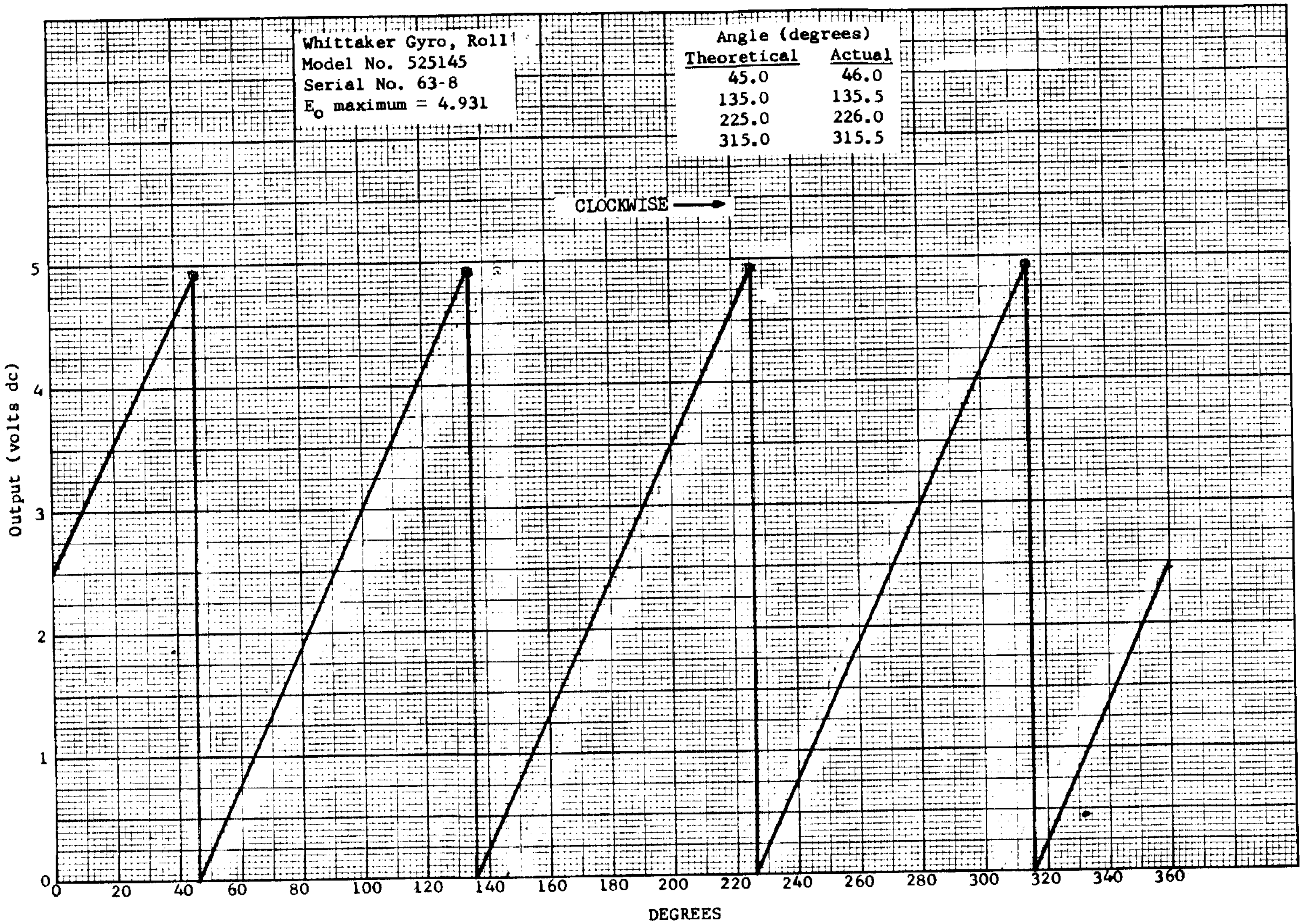
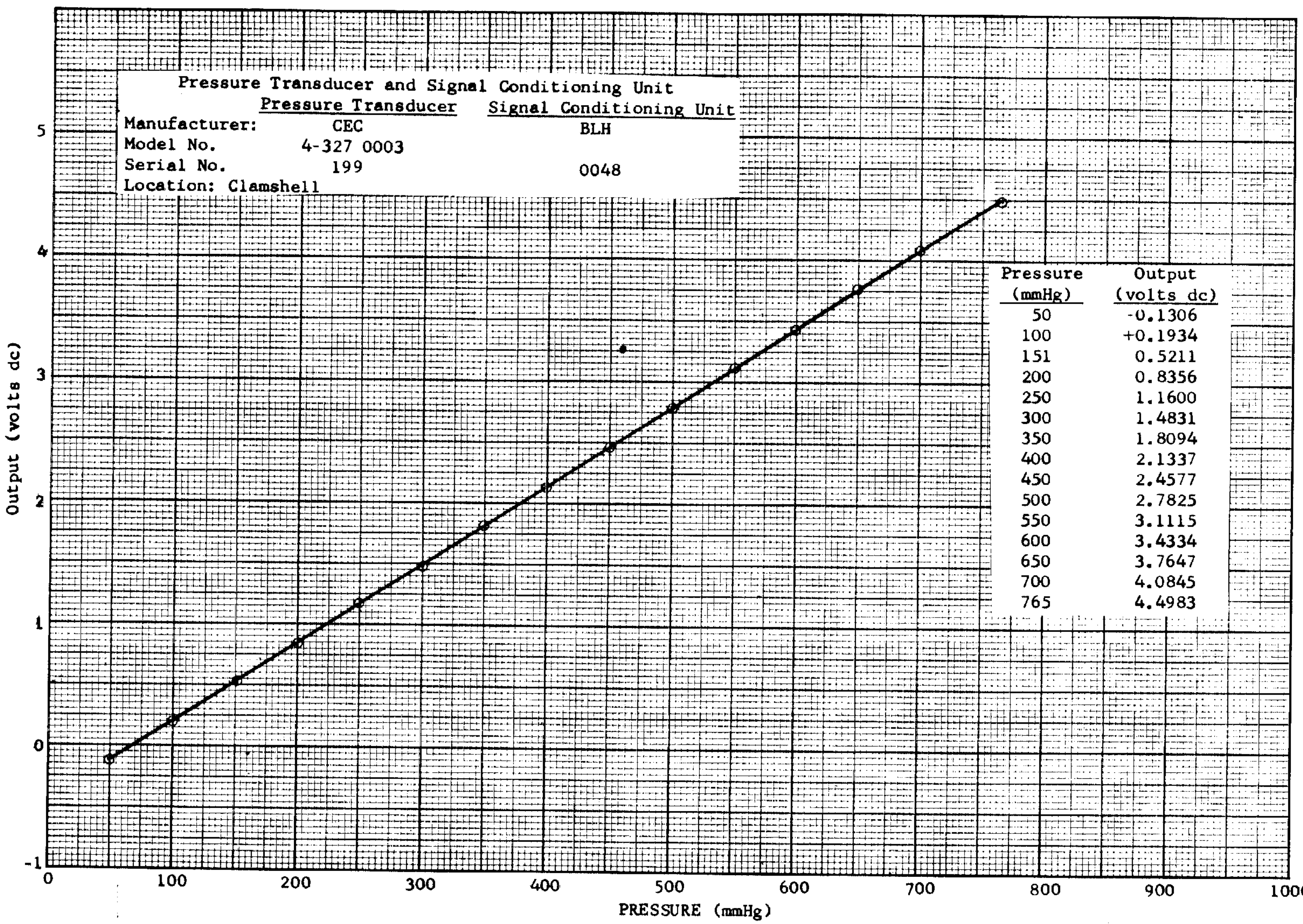


Figure A-12. Stable Platform, Type 525145 (Roll), Calibration Curve



Pressure (mmHg)	Output (volts dc)
50	-0.1306
100	+0.1934
151	0.5211
200	0.8356
250	1.1600
300	1.4831
350	1.8094
400	2.1337
450	2.4577
500	2.7825
550	3.1115
600	3.4334
650	3.7647
700	4.0845
765	4.4983

Figure A-13. Pressure Transducer, Type 4-327-0003, Calibration Curve

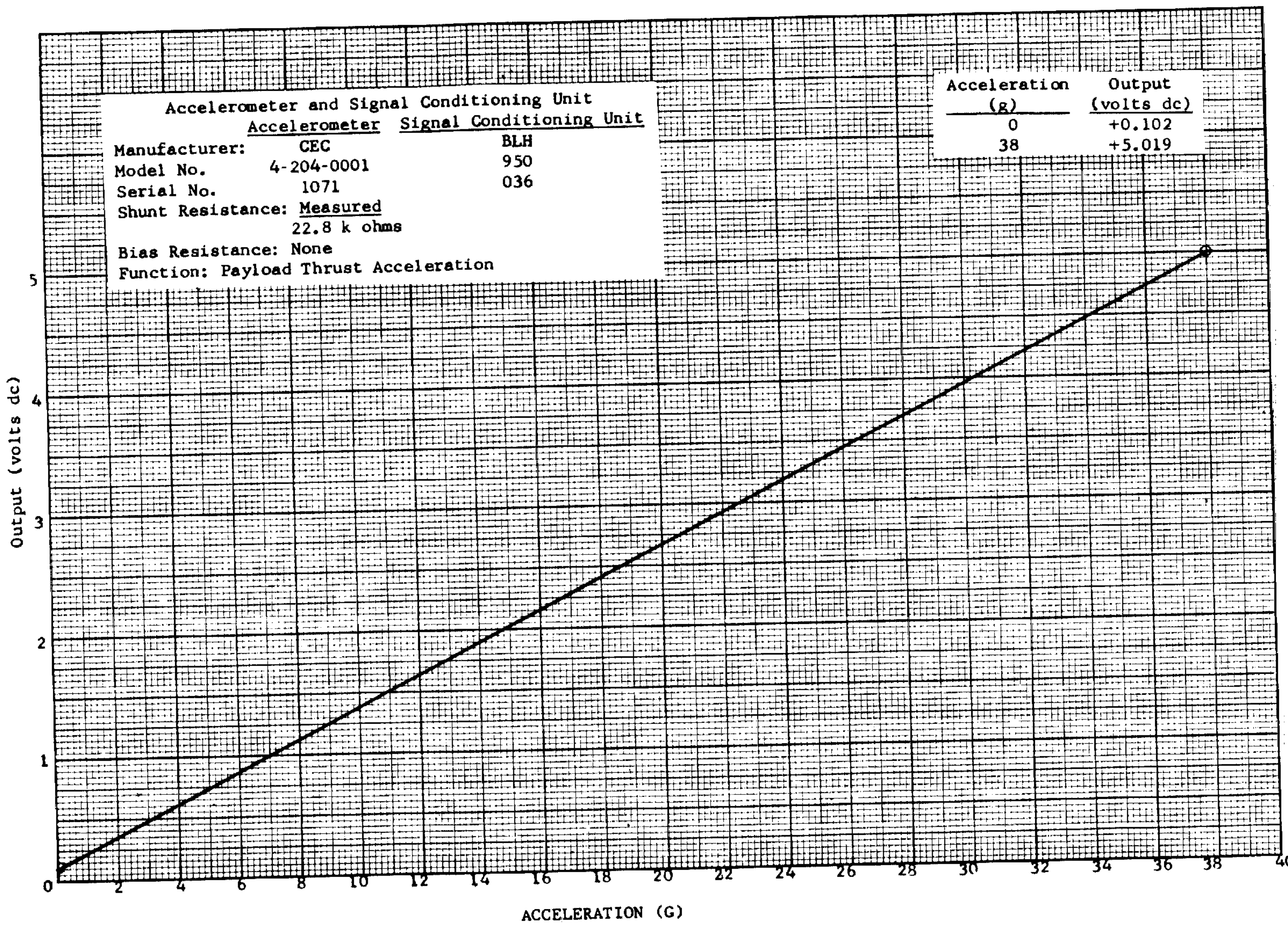


Figure A-14. Accelerometer, Type 4-204-0001, Calibration Curve

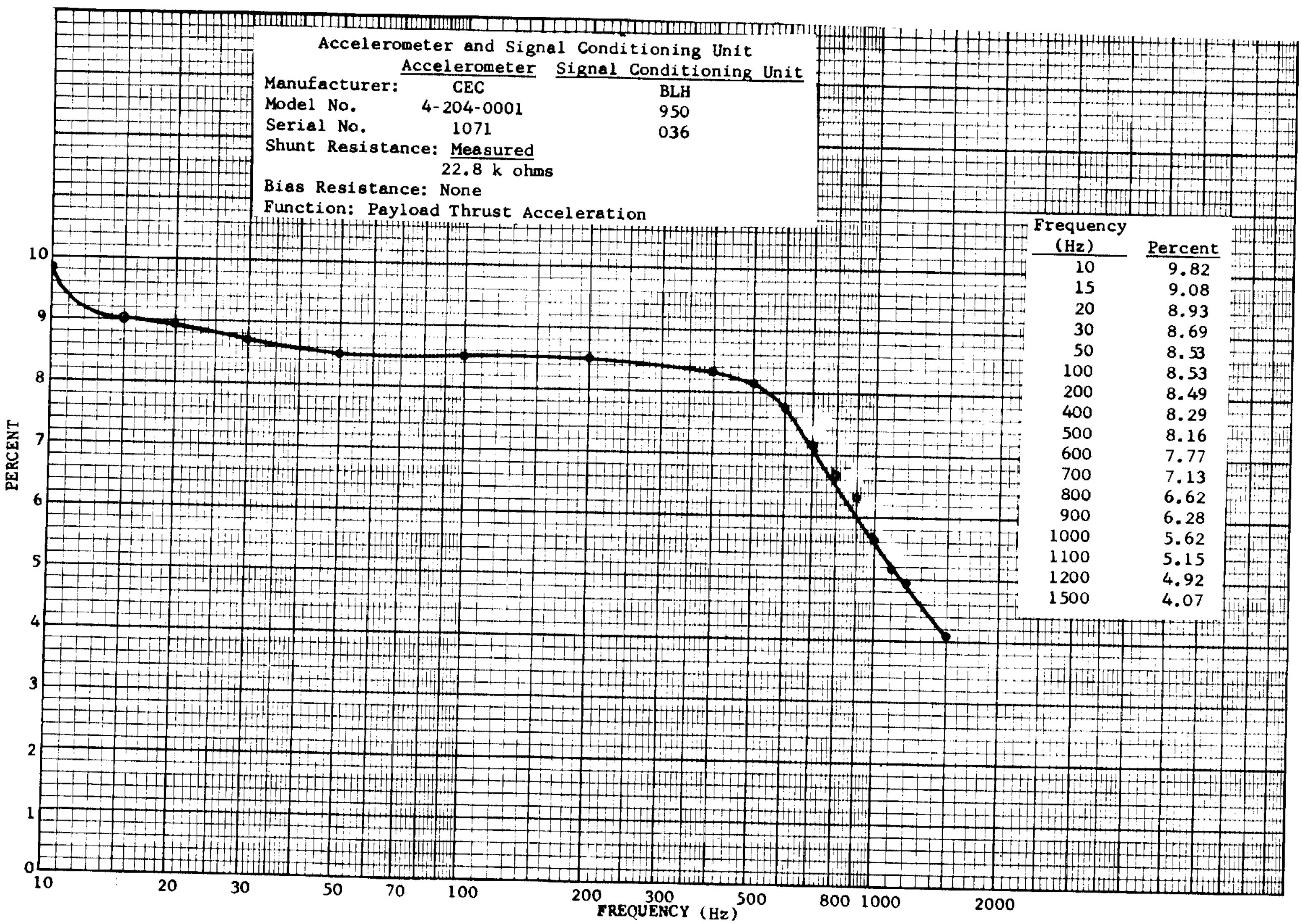


Figure A-15. Accelerometer, Type 4-204-0001, Frequency Response Curve

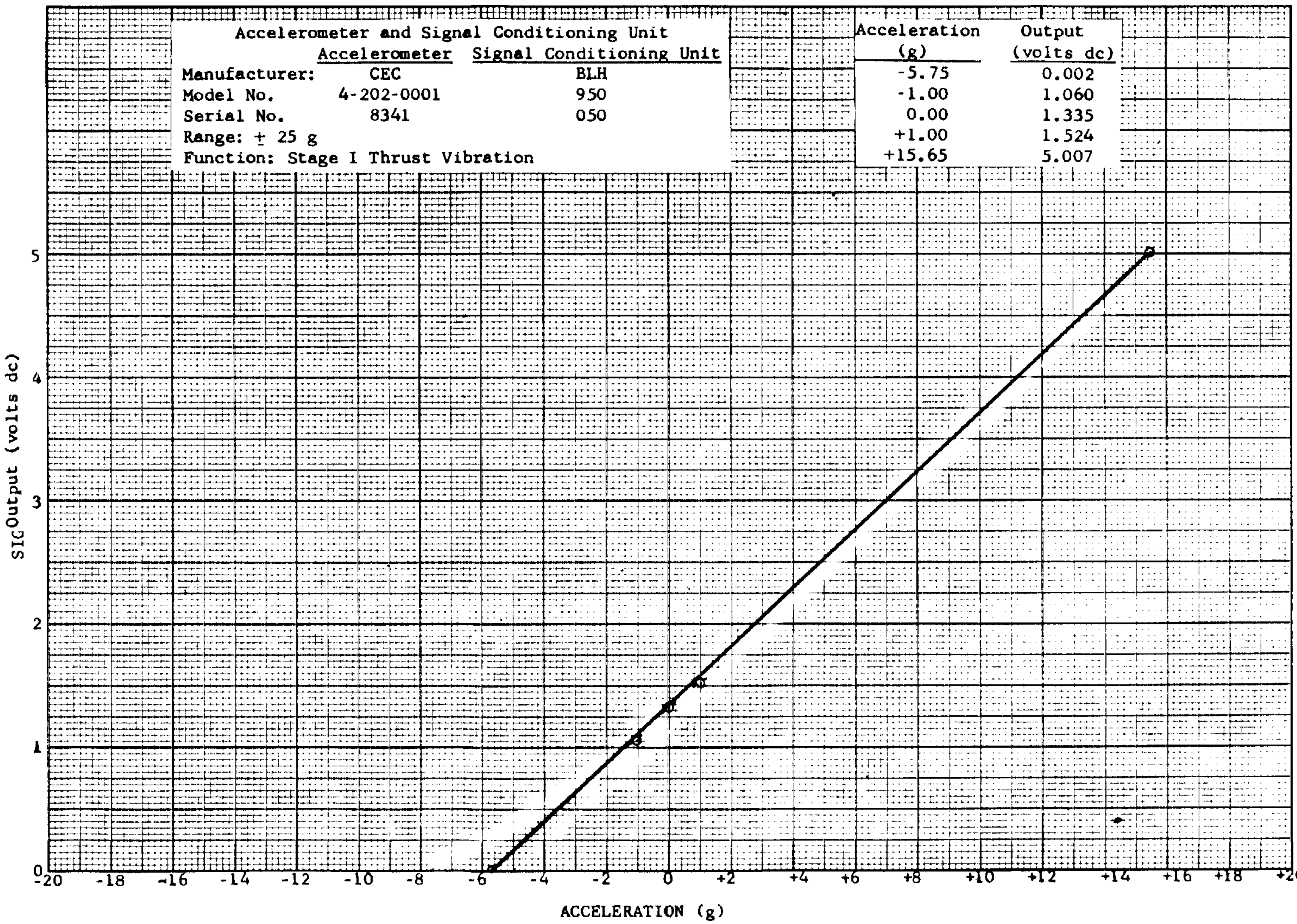


Figure A-16. Vibration Sensor, Type 4-202-0001, Calibration Curve

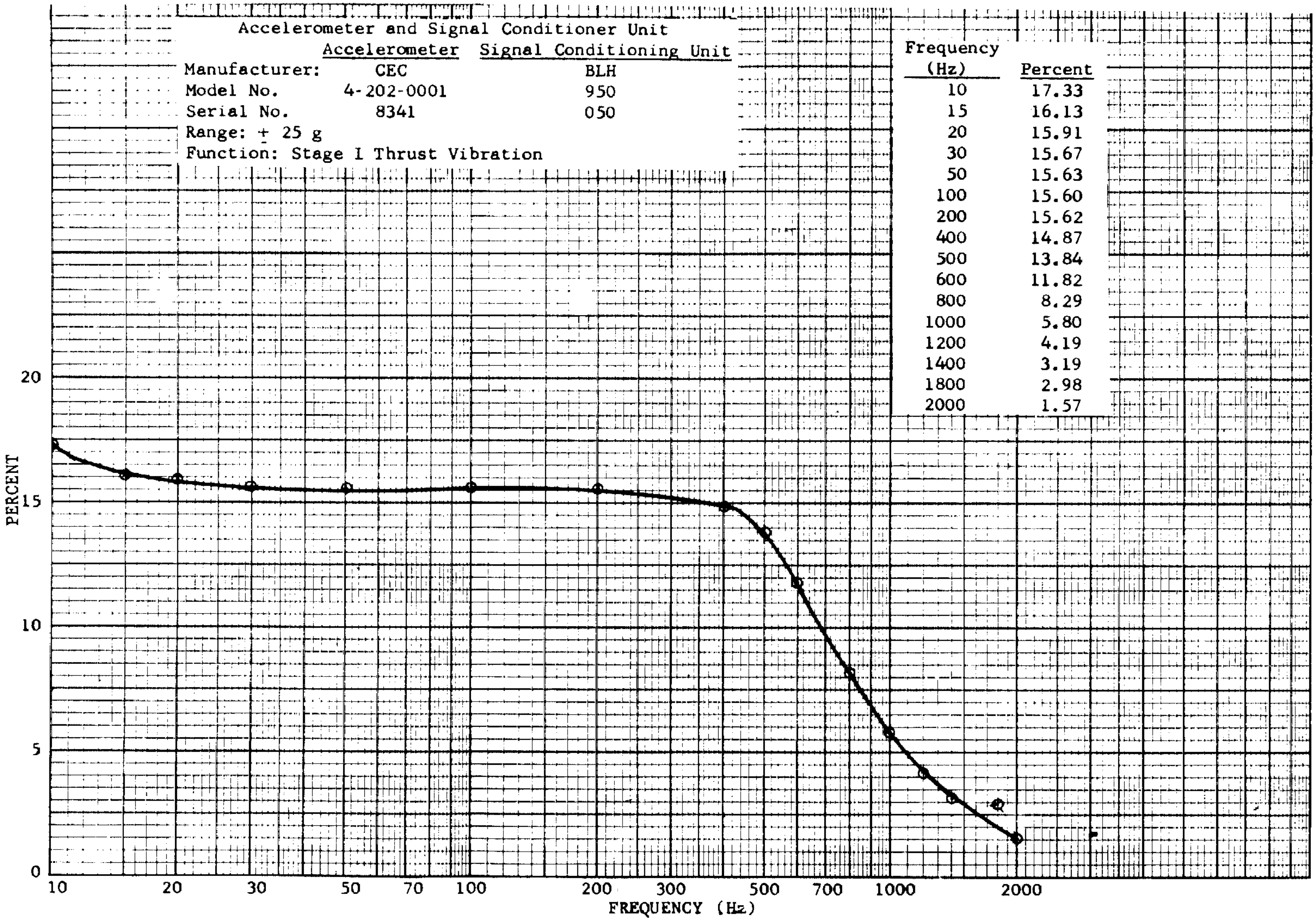
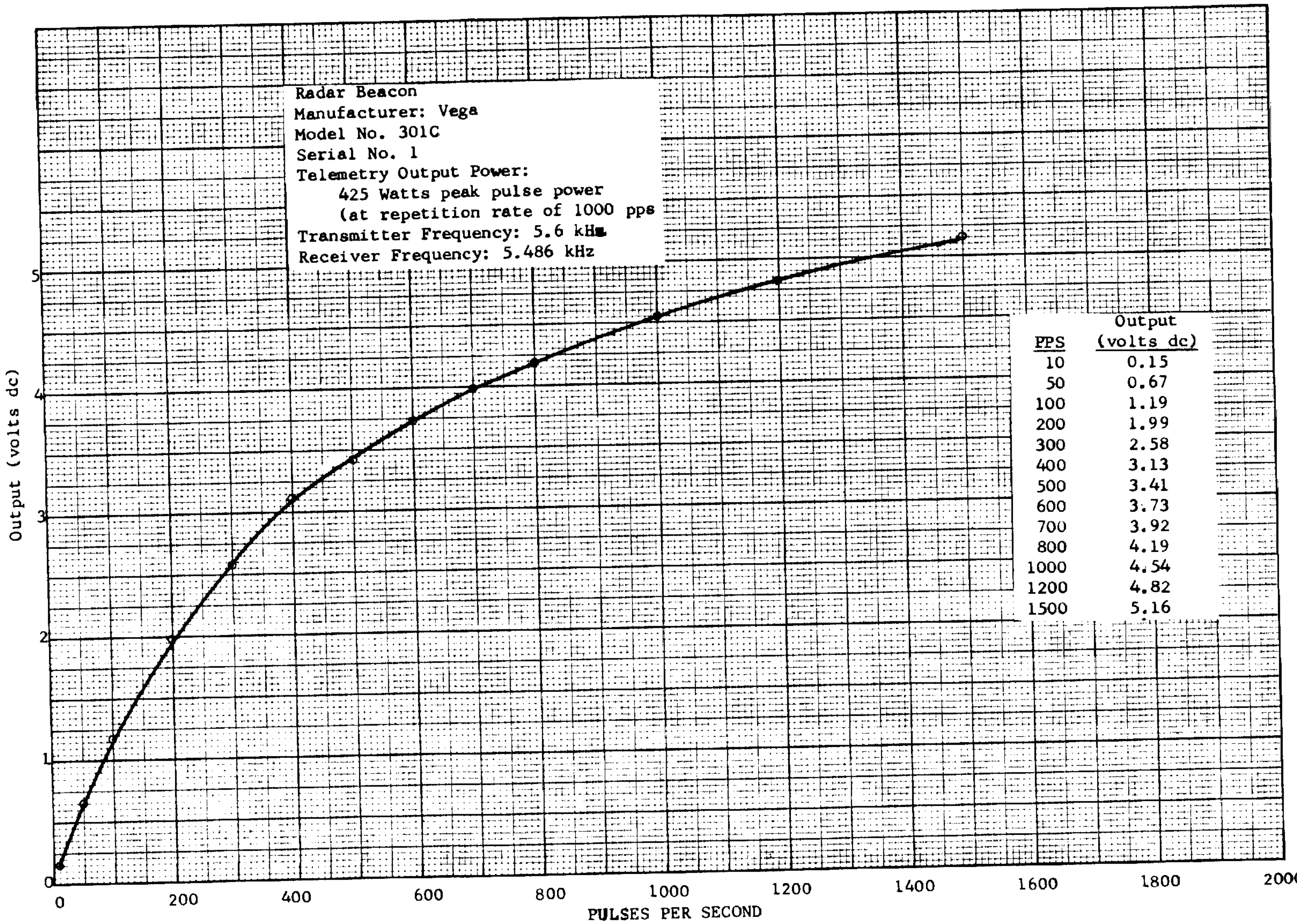


Figure A-17. Vibration Sensor, Type 4-202-0001, Frequency Response Curve



PPS	Output (volts dc)
10	0.15
50	0.67
100	1.19
200	1.99
300	2.58
400	3.13
500	3.41
600	3.73
700	3.92
800	4.19
1000	4.54
1200	4.82
1500	5.16

Figure A-18. Radar Beacon, Telemetry Output Curve

APPENDIX B

TELEMETRY TRANSMITTING ANTENNA SMITH CHARTS AND RADIATION PATTERNS

Figures B-1 through B-3 of Appendix B contain Smith chart plots of each Flight 16.02 GT rocketborne telemetry antenna. Figures B-4 through B-11 contain radiation patterns measured at intervals of 60 degrees as determined on the standard spherical coordinate reference system. (A complete set of curves is available from the Sounding Rocket Instrumentation Section.) Patterns for the 240.2 megahertz and 231.4 megahertz and 244.3 megahertz antennas are included. VSWR plots versus various frequencies for the radar beacon folded valentine antenna are supplied in Figure B-12.

IMPEDANCE COORDINATES—50-OHM CHARACTERISTIC IMPEDANCE

MODEL 2.005
SERIAL NOS. 404, 405
FREQUENCY 231.4 MHz

FEBRUARY 10, 1964

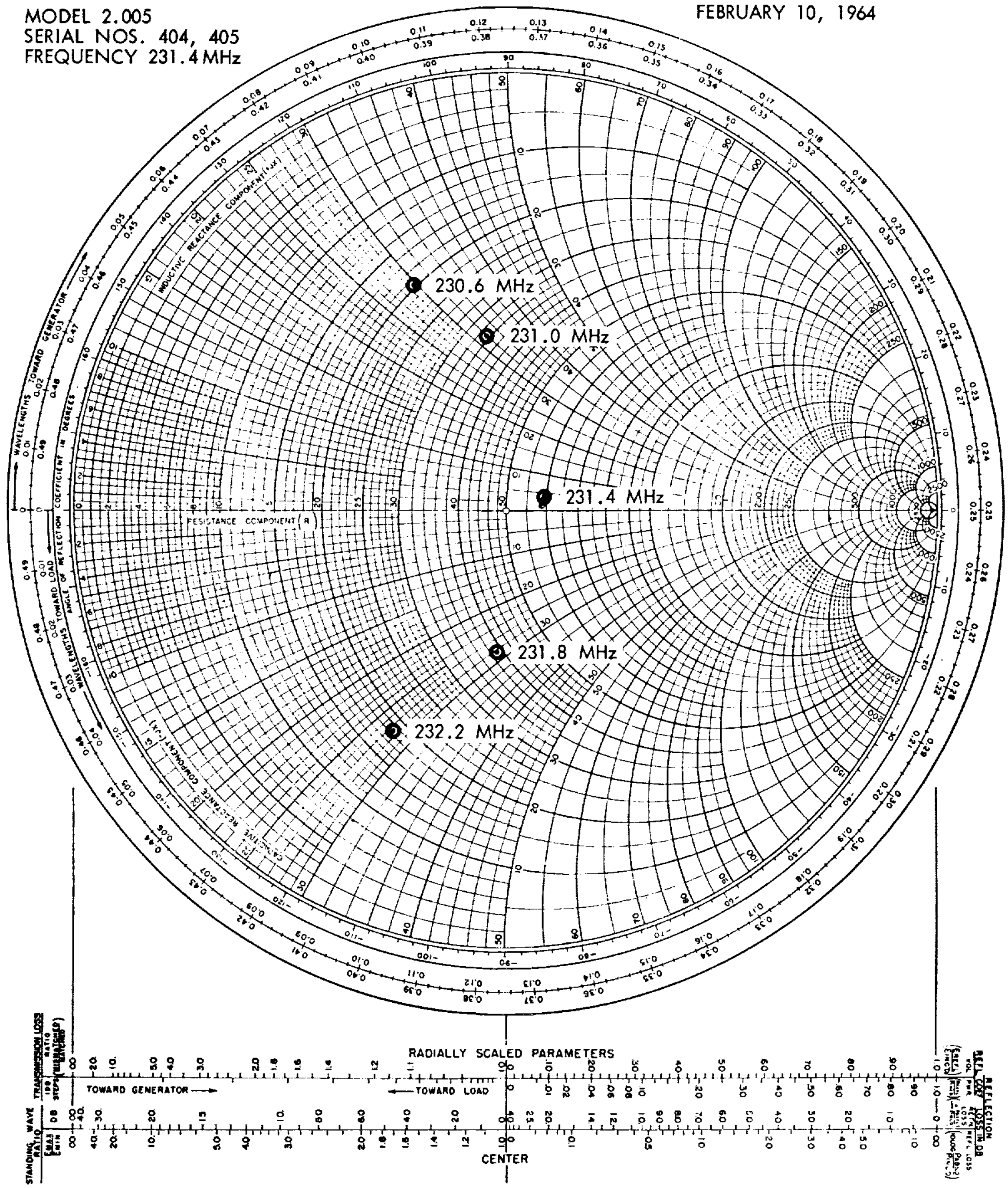


Figure B-1. Polar Impedance Plot, 231.4 MHz, Rocket 16.02

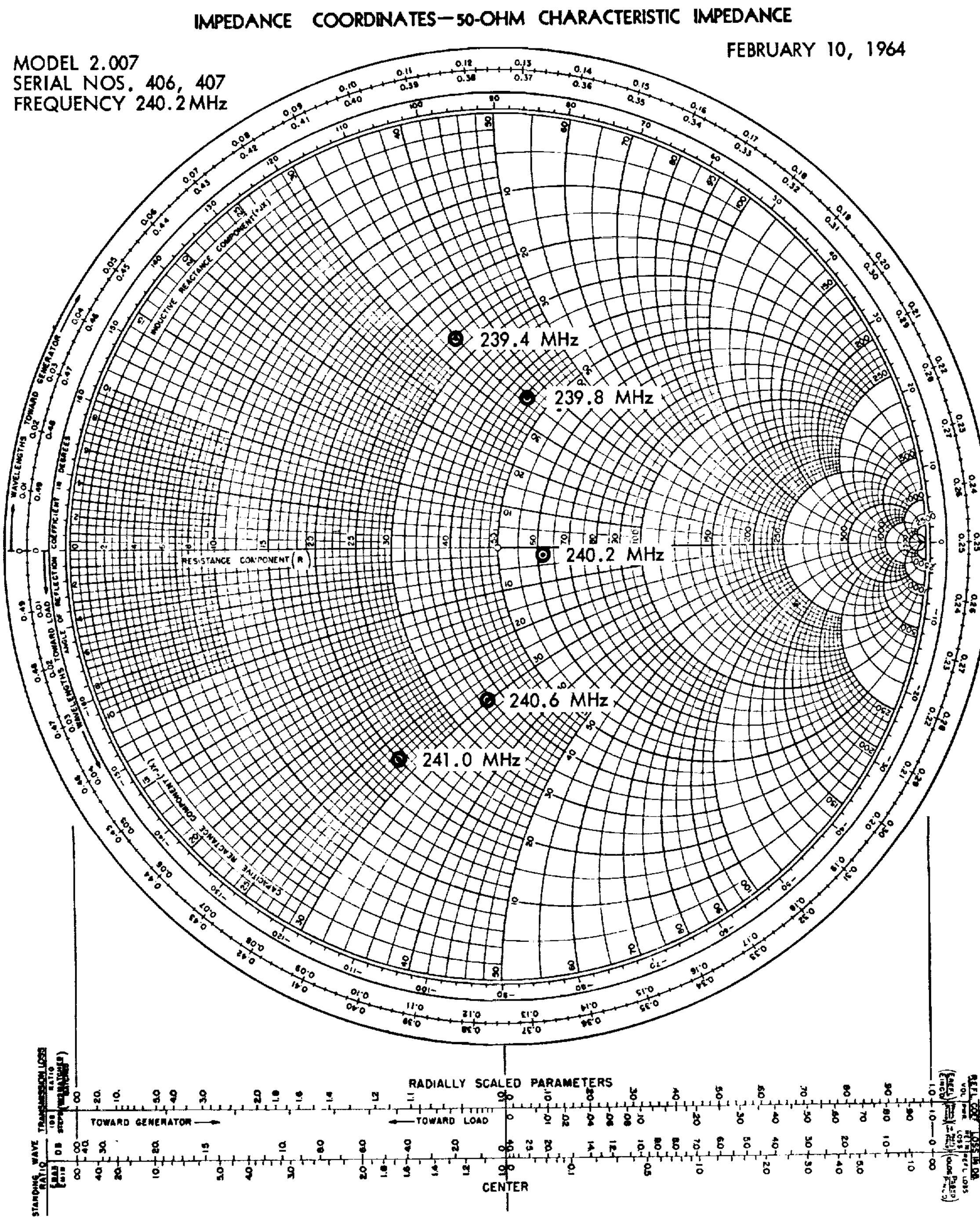


Figure B-2. Polar Impedance Plot, 240.2 MHz, Rocket 16.02

IMPEDANCE COORDINATES—50-OHM CHARACTERISTIC IMPEDANCE

MODEL 2.007
SERIAL NOS. 906, 907
FREQUENCY 244.3 MHz

FEBRUARY 10, 1964

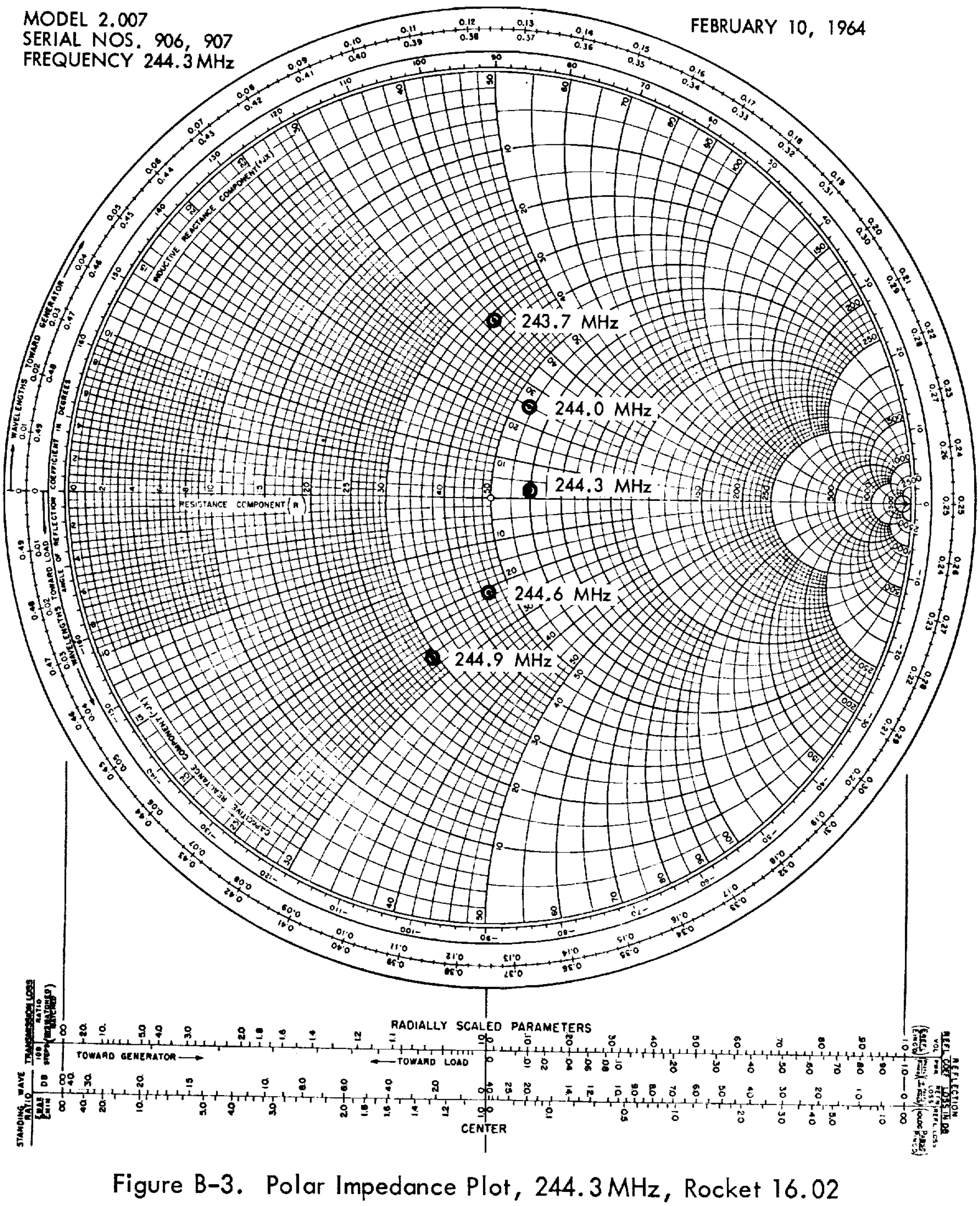
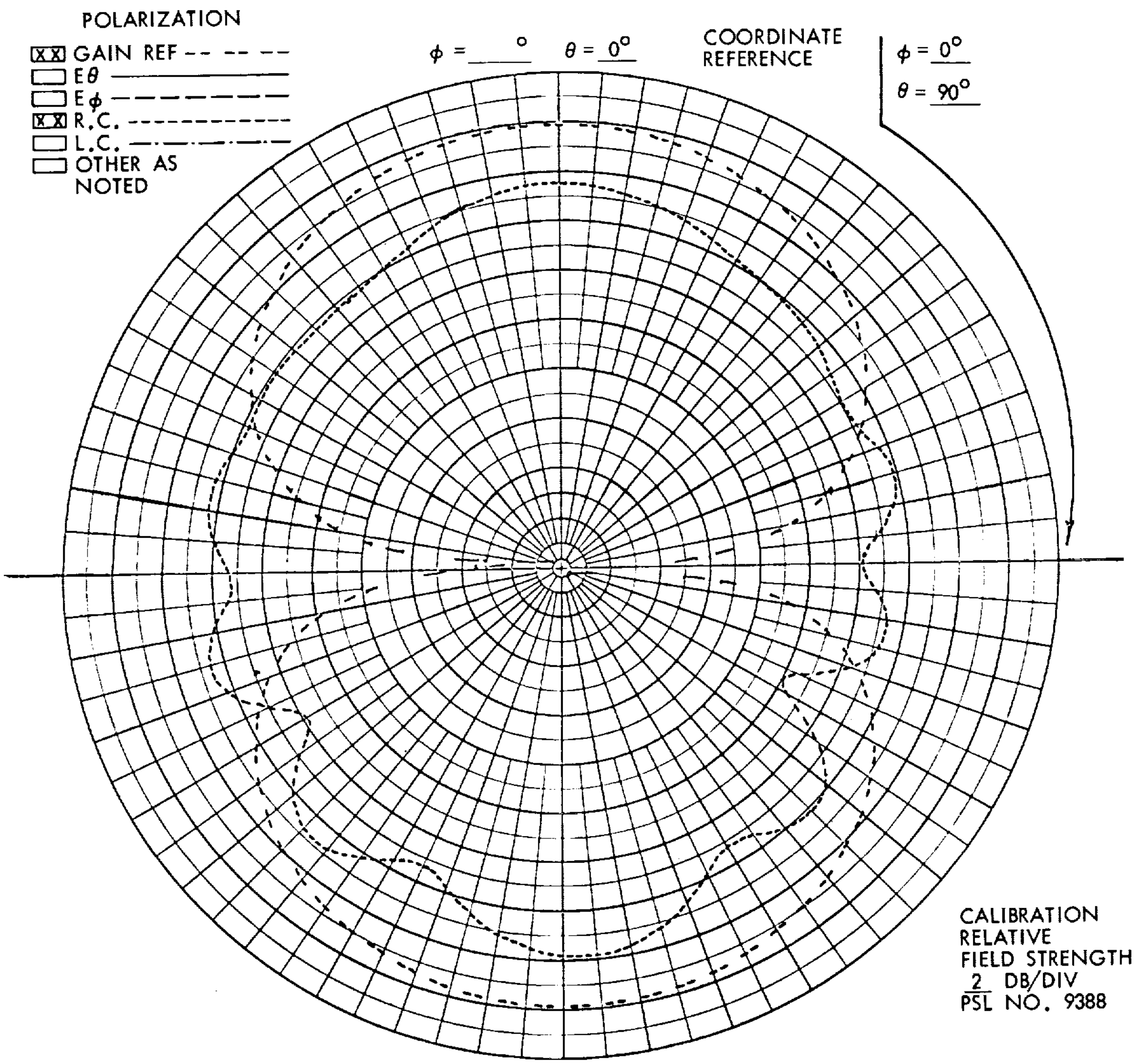


Figure B-3. Polar Impedance Plot, 244.3 MHz, Rocket 16.02

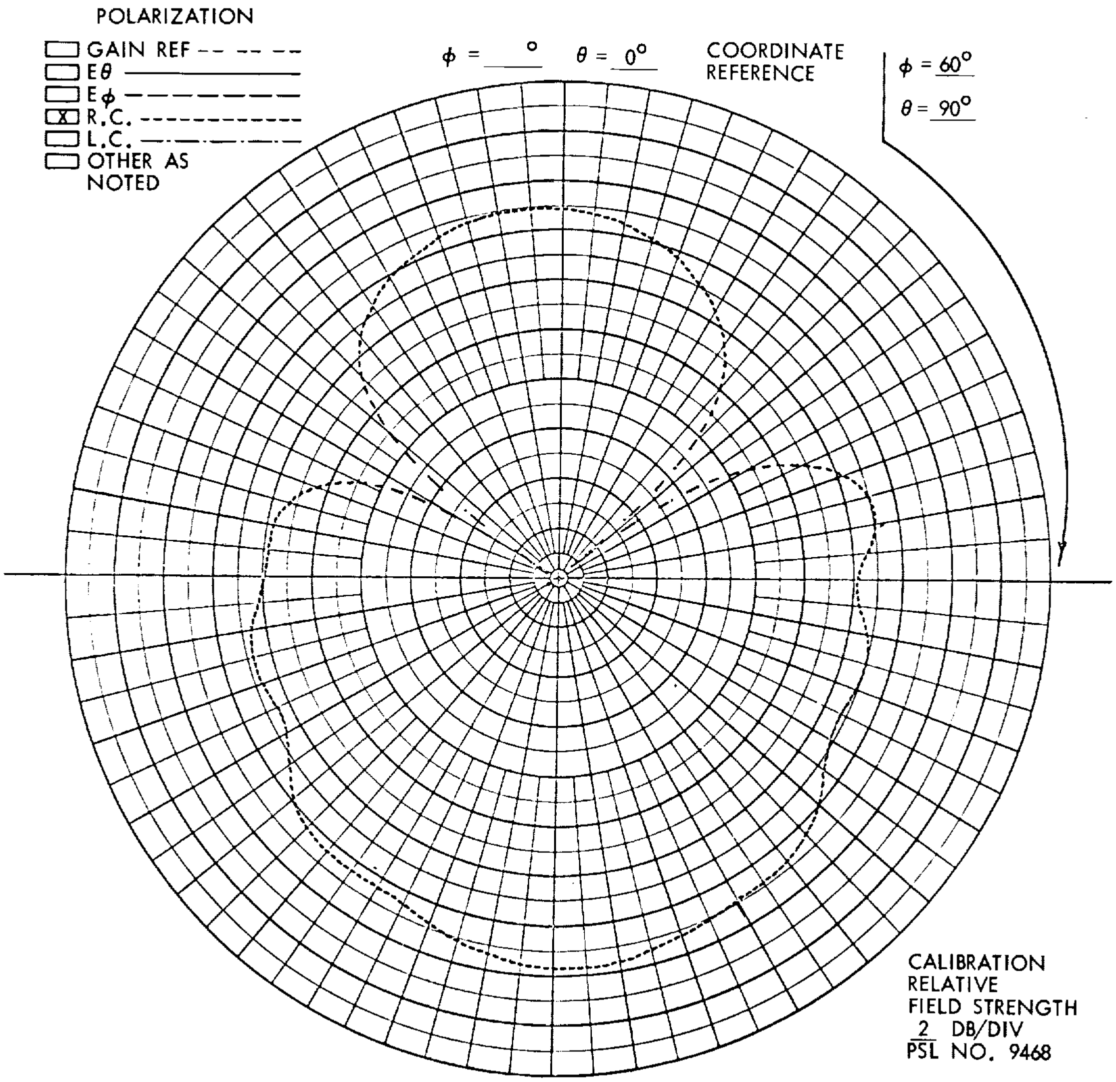


FREQUENCY 231.4 MHz

ANTENNA AN ARRAY OF TWO MODEL 2.005 ANTENNAS FED 180° OUT OF PHASE

REMARKS THE ARRAY WAS MOUNTED UNDER THE FIBERGLAS SHELL OF THE ASTROBEE 1500. THE GAIN REFERENCE USED WAS A STODDART HALF-WAVE DIPOLE.

Figure B-4. Standard Coordinate Reference System, 231.4 MHz, $\phi = 0^\circ$, $\theta = 90^\circ$

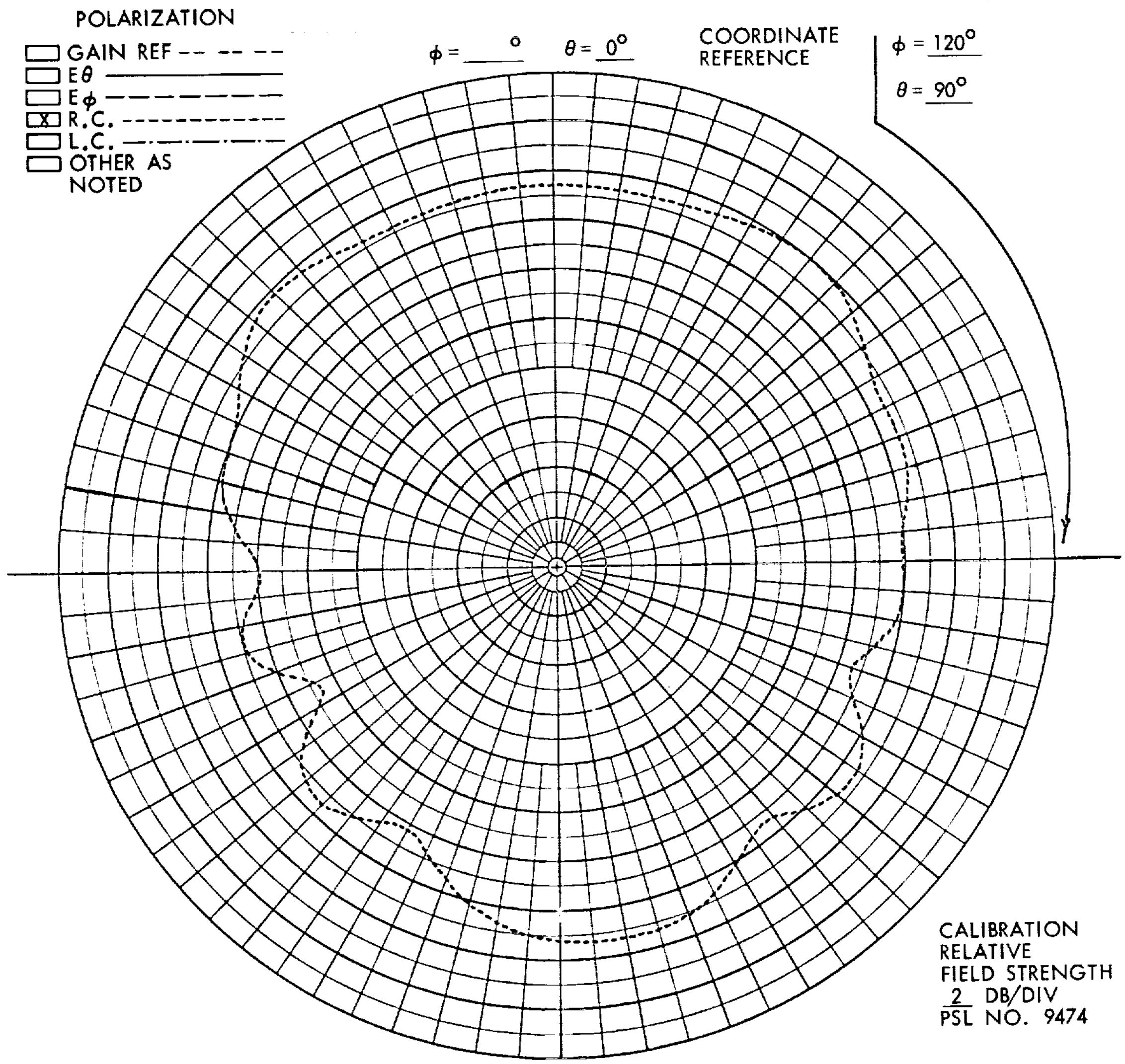


FREQUENCY 231.4 MHz

ANTENNA AN ARRAY OF TWO MODEL 2.005 ANTENNAS FED 180° OUT OF PHASE

REMARKS

Figure B-5. Standard Coordinate Reference System, 231.4 MHz, $\phi = 60°$, $\theta = 90°$

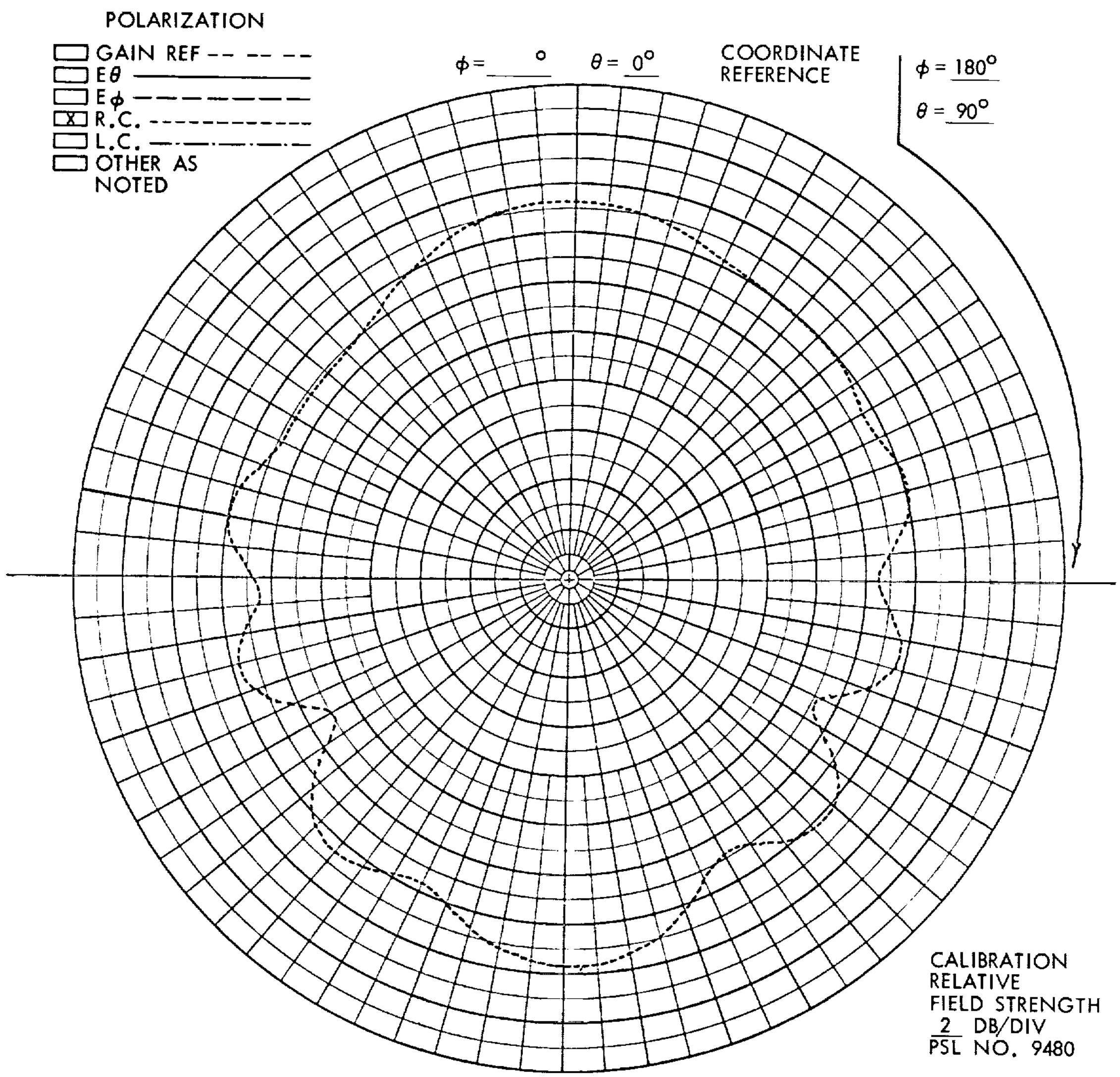


FREQUENCY 231.4 MHz

ANTENNA AN ARRAY OF TWO MODEL 2.005 ANTENNAS FED 180° OUT OF PHASE

REMARKS

Figure B-6. Standard Coordinate Reference System, 231.4 MHz, ϕ = 120°, θ = 90°

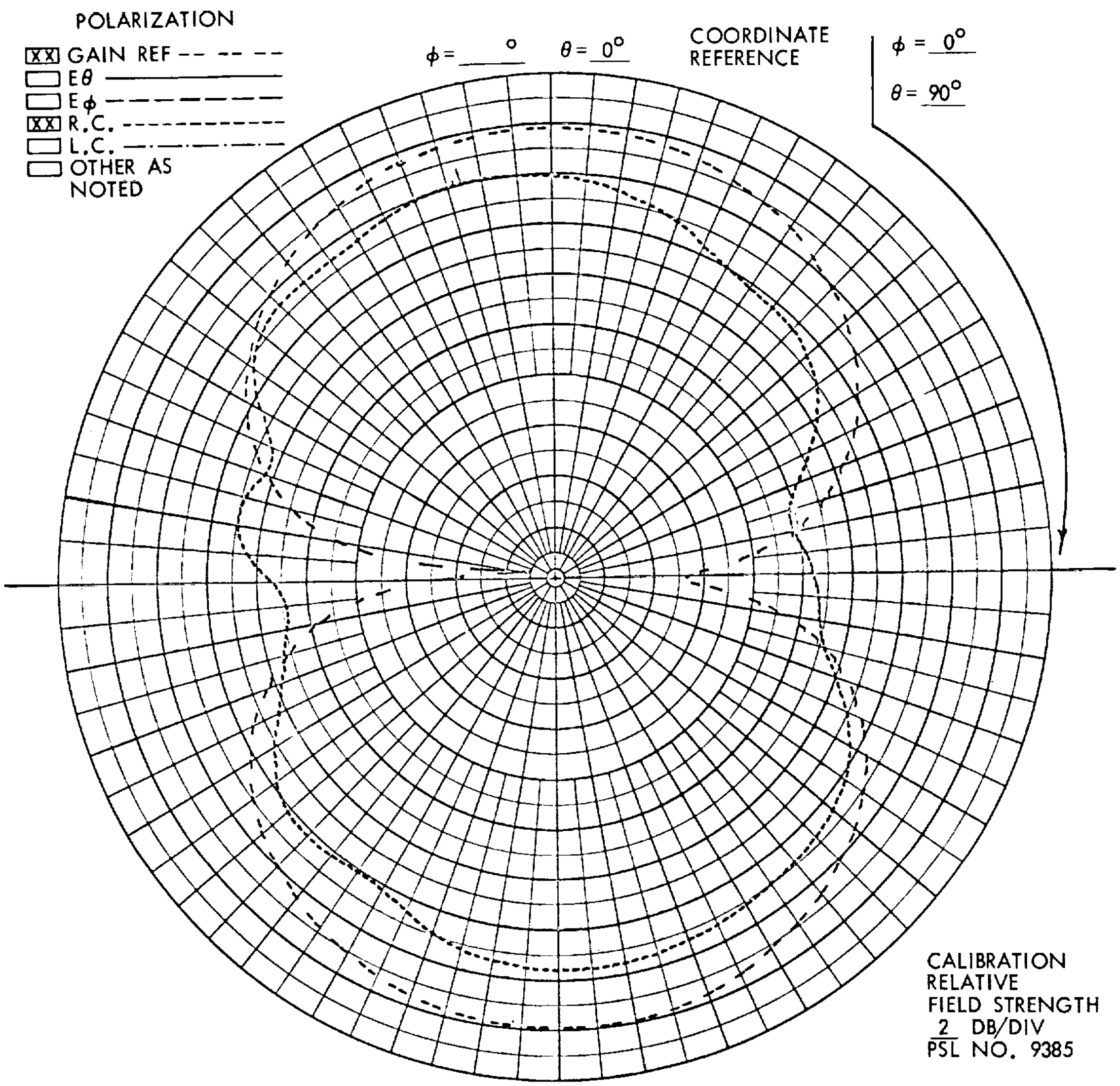


FREQUENCY 231.4 MHz

ANTENNA AN ARRAY OF TWO MODEL 2.005 ANTENNAS FED 180° OUT OF PHASE

REMARKS

Figure B-7. Standard Coordinate Reference System, 231.4 MHz, $\phi = 180°$, $\theta = 90°$

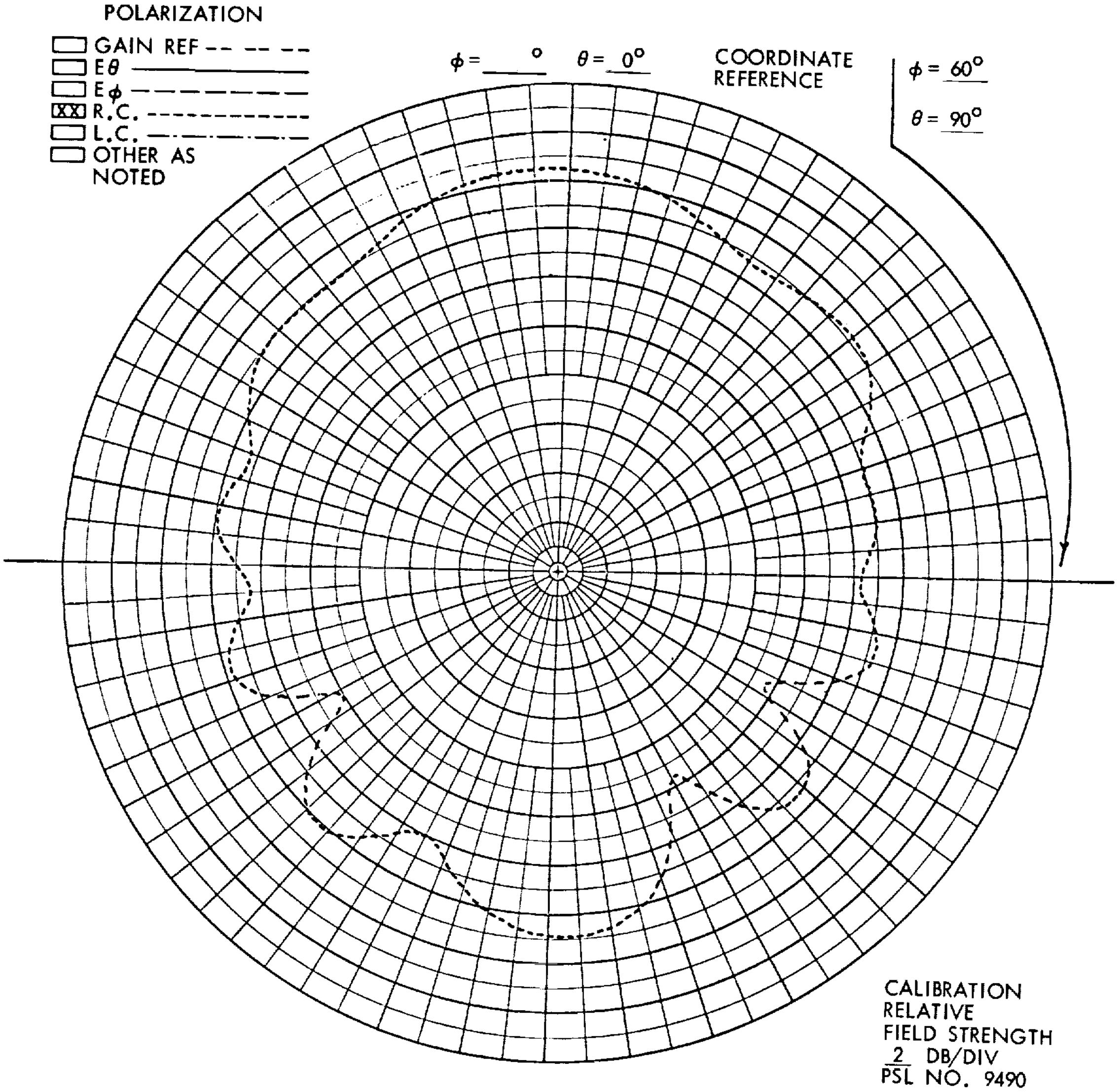


FREQUENCY 240.2 MHz

ANTENNA AN ARRAY OF TWO MODEL 2.007 ANTENNAS FED 180° OUT OF PHASE

REMARKS THE ARRAY WAS MOUNTED UNDER THE FIBERGLAS SHELL OF THE ASTROBEE 1500. THE GAIN REFERENCE USED WAS A STODDART HALF-WAVE DIPOLE.

Figure B-8. Standard Coordinate Reference System, 240.2 MHz, $\phi = 0°$, $\theta = 90°$

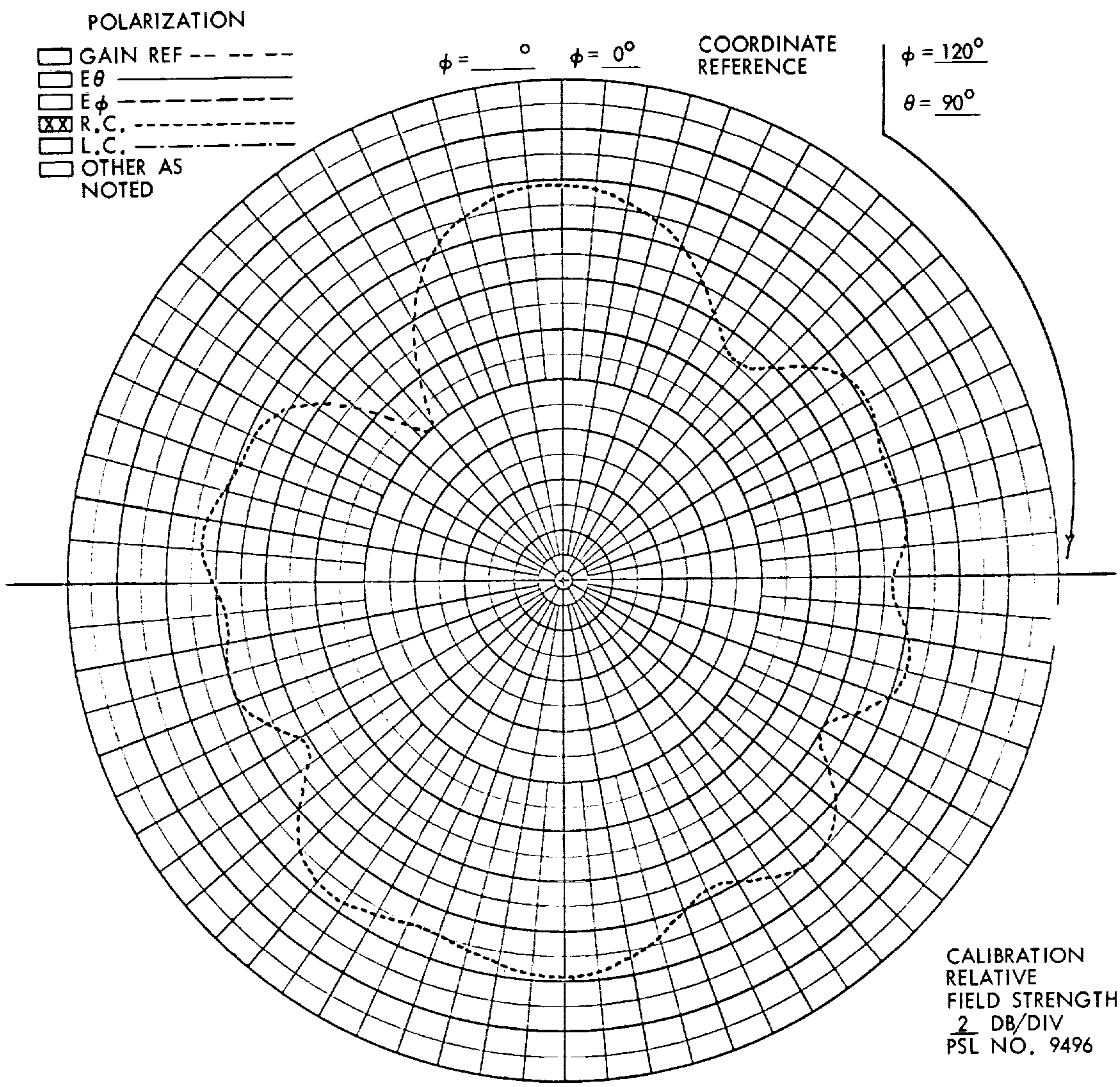


FREQUENCY 240.2 MHz

ANTENNA AN ARRAY OF TWO MODEL 2.007 ANTENNAS FED 180° OUT OF PHASE

REMARKS

Figure B-9. Standard Coordinate Reference System, 240.2 MHz, ϕ = 60°, θ = 90°

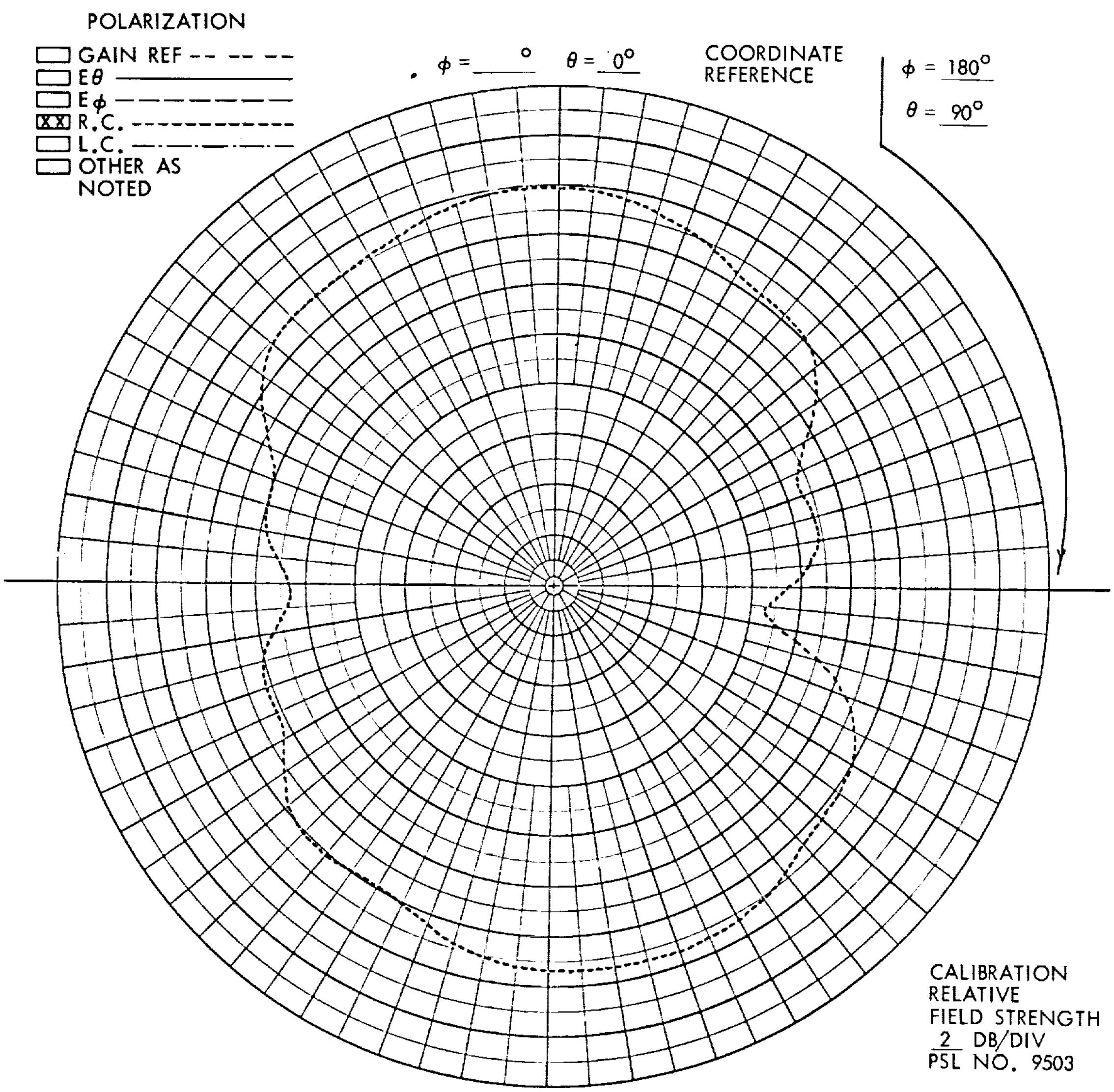


FREQUENCY 240.2 MHz

ANTENNA AN ARRAY OF TWO MODEL 2.007 ANTENNAS FED 180° OUT OF PHASE

REMARKS

Figure B-10. Standard Coordinate Reference System, 240.2 MHz, $\phi = 120°$, $\theta = 90°$



FREQUENCY 240.2 MHz

ANTENNA AN ARRAY OF TWO MODEL 2.007 ANTENNAS FED 180° OUT OF PHASE

REMARKS

Figure B-11. Standard Coordinate Reference System, 240.2 MHz, ϕ = 180°, θ = 90°

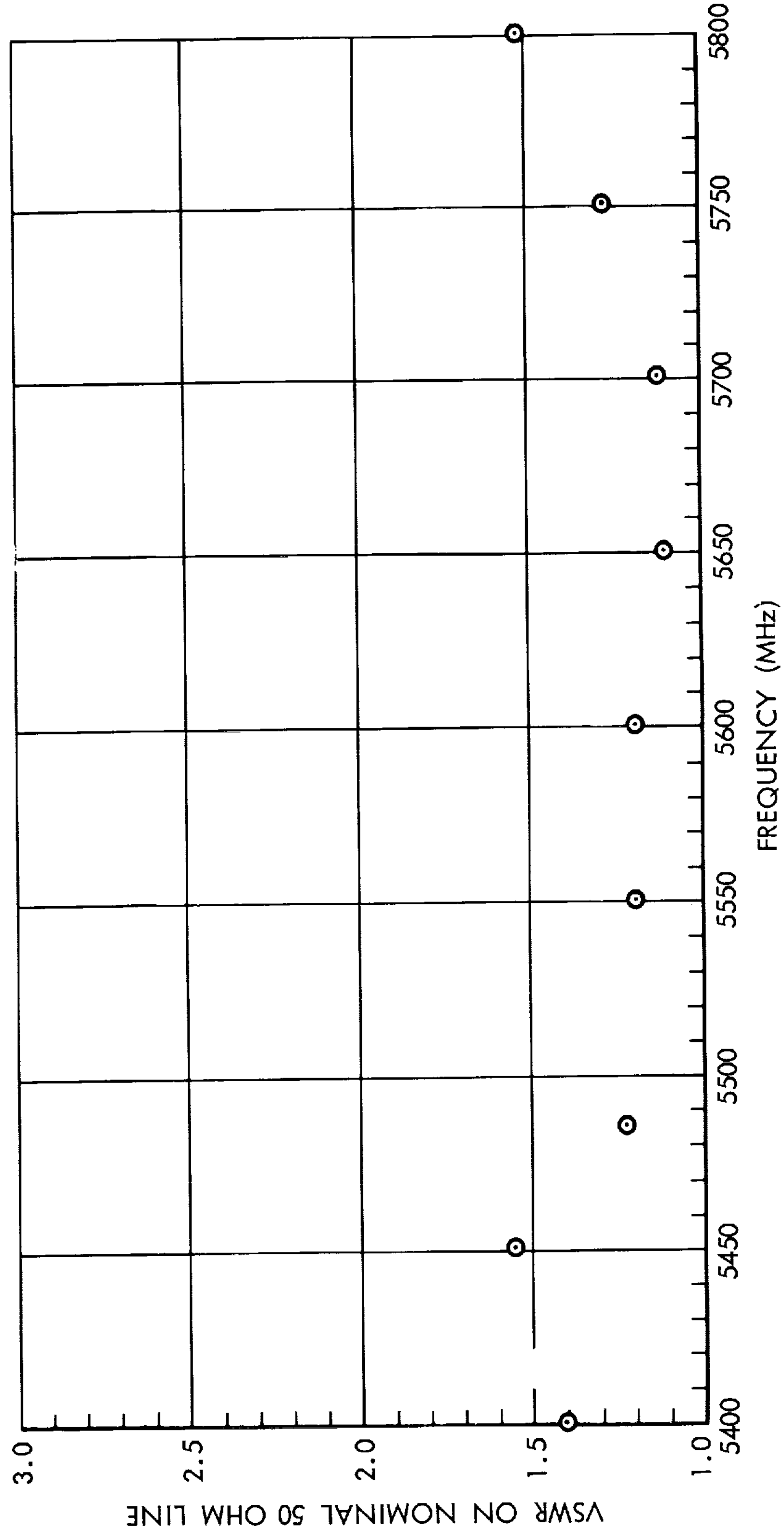


Figure B-12. Radar Beacon Antenna, VSWR Curve

APPENDIX C

ELECTRICAL SYSTEM CHECKOUT PROCEDURE

Appendix C contains the Astrobee 1500, Flight 16.02, electrical system (including the Sequencer unit) checkout procedure. The tests are performed using a 28-volt dc power supply and checkout unit.

Note that all vehicle igniters, squibs, and explosive bolts must be grounded and isolated from the electrical system before beginning the procedure.

ASTROBEE 1500 ELECTRICAL SYSTEM CHECKOUT PROCEDURE

A. Connect the Astrobee 1500 Checkout unit and harnesses to the electrical system.

B. Place Checkout unit switches in the following positions:

1. GND PWR (ground power) switch in the down (open) position.

2. CHARGE switch in the down (open) position.

3. TPS (thrust pressure switch) in the down (normally closed) position.

4. LO SIM (liftoff simulator) switch in the down (closed) position.

5. ARM switch in the down (open) position.

6. DISARM switch in the down (open) position.

7. FUNCTIONAL-CONTINUITY switch in the FUNCTIONAL position.

8. CONTINUITY switch in the METER CHECK position.

C. Safety short check:

1. Disconnect the P13 battery connector and the positive leads from the battery in the explosive bolt firing unit. Remove both shorting plugs.

2. Allow both Raymond timers to time out. There should be no change in the meters.

3. Close the GND PWR switch. There should be no change in the meters.

4. Close the CHARGE switch. The VOLTAGE meter should read 28 volts dc.

5. Place the LO SIM switch in the up (open) position.

6. Momentarily close the ARM switch. The ARM indicator should be illuminated.

7. Place the TPS switch in the up (normally open) position. There should be no change in the meters.

8. Place the TPS switch in the down (normally closed) position. There should be no change in the meters.

9. Place the FUNCTIONAL-CONTINUITY switch in the CONTINUITY position, and wait 15 seconds.

10. Place the CONTINUITY switch in the following positions:

    a. METER CHECK position should indicate zero on the RESISTANCE meter.

    b. SPIN AB position should indicate no continuity on the RESISTANCE meter.

    c. SPIN CB position should indicate no continuity on the RESISTANCE meter.

    d. BOLTS BC position should indicate no continuity on the RESISTANCE meter.

    e. BOLTS AD position should indicate no continuity on the RESISTANCE meter.

    f. IGNITION CD position should indicate no continuity on the RESISTANCE meter.

    g. IGNITION AB position should indicate no continuity on the RESISTANCE meter.

    Return the CONTINUITY switch to the METER CHECK position.

11. Connect the Sequence unit shorting plug.

12. Place the CONTINUITY switch in the following positions:

    a. SPIN AB position should indicate continuity on the RESISTANCE meter.

    b. SPIN CB position should indicate continuity on the RESISTANCE meter.

    c. BOLTS BC position should indicate continuity on the RESISTANCE meter.

d. BOLTS AD position should indicate no continuity on the RESISTANCE meter.

e. IGNITION CD position should indicate continuity on the RESISTANCE meter.

f. IGNITION AB position should indicate continuity on the RESISTANCE meter.

Return the CONTINUITY switch to the METER CHECK position.

13. Connect the Interstage shorting plug, and disconnect the Sequence unit shorting plug.

14. Place the CONTINUITY switch in the following positions:

    a. SPIN AB position should indicate continuity on the RESISTANCE meter.

    b. SPIN CB position should indicate continuity on the RESISTANCE meter.

    c. BOLTS BC position should indicate continuity on the RESISTANCE meter.

    d. BOLTS AD position should indicate continuity on the RESISTANCE meter.

    e. IGNITION CD position should indicate continuity on the RESISTANCE meter.

    f. IGNITION AB position should indicate continuity on the RESISTANCE meter.

15. Momentarily close the DISARM switch and observe that the ARM indicator is not illuminated.

16. Close the LO SIM switch.

17. Remove the Interstage shorting plug.

18. Open the GND PWR switch, and observe that the VOLTAGE meter indicates zero voltage.

19. Open the CHARGE switch.

20. Reset both Raymond timers.

21. Connect the positive lead of the battery in the explosive bolt firing unit. A voltage should be indicated on the VOLTAGE meter.

D. Disarm check:

1. Close the GND PWR switch.

2. Momentarily close t e ARM switch and observe that the ARM indicator is illuminated.

3. Momentarily close t DISARM switch and observe that the ARM indicator is not illuminated.

4. Open the GND PWR switch.

E. Sequence unit ordnance-safety short-check (both timers reset):

1. Place the FUNCTIONAL-CONTINUITY switch in the CONTINUITY position.

2. Close the GND PWR switch.

3. Place the CONTINUITY switch in the following positions:

   a. METER CHECK position should indicate zero on the RESISTANCE meter.

   b. SPIN AB position should indicate continuity on the RESISTANCE meter.

   c. SPIN CB position should indicate continuity on the RESISTANCE meter.

   d. BOLTS BC position should indicate continuity on the RESISTANCE meter.

   e. BOLTS AD position should indicate continuity on the RESISTANCE meter.

f. IGNITION CD position should indicate continuity on the RESISTANCE meter.

g. IGNITION AB position should indicate continuity on the RESISTANCE meter.

Return the CONTINUITY switch to the METER CHECK position.

4. Momentarily energize the ARM switch.

5. Place the CONTINUITY switch in the following positions:

a. SPIN AB position should indicate continuity on the RESISTANCE meter.

b. SPIN CB position should indicate continuity on the RESISTANCE meter.

c. BOLT BC position should indicate continuity on the RESISTANCE meter.

d. BOLT AD position should indicate continuity on the RESISTANCE meter.

e. IGNITION CD position should indicate continuity on the RESISTANCE meter.

f. IGNITION AB position should indicate continuity on the RESISTANCE meter.

Return the CONTINUITY switch to the METER CHECK position, and the FUNCTIONAL-CONTINUITY switch to the FUNCTIONAL position.

6. Close and open the DISARM switch.

7. Open the GND PWR switch.

F. Liftoff switch check (TPS):

1. Close the GND PWR switch. There should be no change in the meters.

2. Momentarily close the ARM switch and observe that ARM indicator is illuminated.

3. Place the TPS switch in the up (normally open) position. There should be no change in the meters.

4. Place the TPS switch in the down (normally closed) position, and observe that ARM indicator is not illuminated.

5. Open the GND PWR switch.

G. Liftoff switch check (timer):

1. Close the GND PWR switch. There should be no change in the meters.

2. Momentarily close the ARM switch and observe that ARM indicator is illuminated.

3. Start the Raymond timer. Approximately 8 seconds after the timer is started, the ARM indicator should go off.

4. Momentarily close the DISARM switch.

5. Open the GND PWR switch.

6. Reset the Raymond timer.

H. Functional check (with explosive bolt unit timer and Raymond timer reset):

1. Close the GND PWR switch. There should be no change in the meters.

2. Momentarily energize the ARM switch and observe that ARM indicator is illuminated.

3. Close LO SIM switch. There should be no change in the meters.

4. Place the TPS switch in the up (normally open) position. There should be no change in the meters.

5. Place the TPS switch in the down (normally closed) position.

   a. After approximately 13.5 seconds, the white spin motor ELEC CONT indicators should be illuminated.

   b. After approximately 15.0 seconds (after TPS switch is down) the white explosive bolt ELEC CONT indicators should be illuminated.

c. Approximately 0.5 seconds after the white explosive bolt ELEC CONT indicators are illuminated, the white 2ND IGN indicator should be illuminated.

6. Close and open the DISARM switch. All indicators should go off.

7. Open the GND PWR switch.

I. Raymond timer check:

1. Check to see that the timer is in the reset position.

2. Close the GND PWR switch. There should be no change in the meters.

3. Close the ARM switch and observe that ARM indicator is illuminated.

4. Move the Raymond timer weight and allow the timer to start.

5. Approximately 48.0 seconds after the timer starts, the yellow spin motor MECH CONT indicators should be illuminated.

6. Approximately 50.0 seconds after the timer starts, the yellow 2ND IGN (M) indicator should come on.

7. Open the ARM switch. There should be no change in the meters.

8. Close and open the DISARM switch. All indicators should go off.

9. Open the GND PWR switch. There should be no change in the meters.

J. Explosive bolt firing unit checkout:

1. Close the GND PWR switch. There should be no change in the meters.

2. Close the ARM switch and observe that ARM indicator is illuminated.

3. Pull the explosive bolt firing unit timer pin. Approximately 1.5 seconds after the pin is pulled, the yellow explosive bolt MECH CONT indicators should come on.

4. Open the ARM switch. There should be no change in the meters.

5. Close and open the DISARM switch. All panel indicators should go off.

6. Open the GND PWR switch. There should be no change in the meters.

APPENDIX D

WALLOPS ISLAND RANGE COUNTDOWN

Appendix D is a schedule of operations performed by range participating activities for preparation and flight of the Astrobee 1500, Flight 16.02 rocket, launched from Wallops Island, Virginia.

T-MINUS: (Hr-Min-Sec)	ITEM	OPERATION
04-00-00	1	Launch high-altitude balloon with corner reflector attached and track to maximum altitude.
	2	Vehicle completely assembled on launcher and protected by environmental shelter.
03-00-00	3	Make ignition circuit check from blockhouse.
02-30-00	4	Ignition circuit checks completed.
	5	Begin removing environmental shelter from vehicle.
	6	Make final lanyard adjustments.
02-10-00	7	Environmental shelter removed.
	8	Photograph fully-assembled vehicle in horizontal position.
02-00-00	9	Photography completed.
02-00-00	10	Remove vehicle internal ignition circuit shorting plug.
	11	Remove safety pin from mechanical timer in second stage circuit.
	12	Adjust interstage door.
	13	Connect battery charging umbilical.
	14	Release chaff-type balloon and track to a 20,000-foot altitude.
	15	Begin releasing theodolite balloons at 10-minute intervals.
	16	FAA Coordinator make air traffic report.
	17	Bermuda Coordinator establish communications via SCAMMA line.
01-55-00	18	Clear launch area and prepare for payload instrumentation and radar beacon checks.

T-MINUS: (Hr-Min-Sec)	ITEM	OPERATION
01-55-00 (Cont.)	19	Begin positioning launcher to nominal launcher settings.
01-50-00	20	C-band radar beacon and telemetry external power ON.
	21	Perform beacon checks with AN/FPS-16 and AN/FPQ-6 radars.
	22	Perform payload instrumentation checks.
01-35-00	23	Switch beacon and telemetry to internal power and perform checks.
01-30-00	24	Launch radiosonde to maximum altitude.
01-20-00	25	Instrumentation checks completed. All power OFF (T/M engineer verify).
	26	Nominal launcher setting completed.
	27	Photograph vehicle in elevated position.
01-10-00	28	Photography completed.
	29	Conduct ignition voltage and short test from blockhouse.
01-05-00	30	Clear area and begin vehicle ignition circuit battery charging (1 amp per 30 minutes). Establish road blocks during first five minutes of charging.
01-00-00	31	Release chaff-type balloon and track to a 20,000-foot altitude.
	32	FAA Coordinator make air traffic report.
	33	Coquina and Goddard Station G Telemetry Coordinators make communications check and inform stations of count
00-35-00	34	Vehicle ignition circuit battery charging completed and checked.
	35	Begin final launcher settings.

T-MINUS: (Hr-Min-Sec)	ITEM	OPERATION
00-30-00	36	FAA Coordinator establish "Hot Line" with FAA.
	37	Coquina and Station G Coordinators establish "Hot Line."
	38	Deploy Kytoon for coastal warning area.
00-25-00	39	Final launcher settings completed.
	40	Launch standard 2.75-inch test rocket with flare.
00-20-00	41	Clear launch area and establish road blocks.
	42	Telemetry and radar beacon external power ON.
00-15-00	43	Begin payload instrumentation checks (beacon and telemetry).
00-10-00	44	Surveillance aircraft clear.
00-07-00	45	Payload instrumentation checks completed.
00-06-00	46	All payload instrumentation switched to internal power.
	47	Perform vehicle onboard ignition circuit arm and disarm through sequencer.
	48	Perform booster (Junior) and Recruit continuity check.
	49	Standby for station checks at T-5 minutes.
00-05-00	50	Clear area for launching and make station checks (acknowledge):

NOTE: Weather Bureau personnel in van at 250-foot Meteorological Tower shall leave their duty station and proceed to Blockhouse No. 2.

Radar 1	Camera 12
Radar 2	Camera 13

T-MINUS: (Hr-Min-Sec)	ITEM	OPERATION	
00-05-00 (Cont.)		Radar 3	Camera 14
		Radar 4	Bermuda Coordinator
		Radar 5	Wallops Telemeter
		Doppler Radar	Goddard Telemetry Station A
		Camera 1	Goddard Telemetry Station H
		Camera 2	Goddard Telemetry Station G
		Camera 6	Payload Control
		Camera 8	Launch Pad Supervisor
		Camera 9	Range Safety
		Camera 10	Range Control Center
00-04-00	51	Goddard payload control confirm payload is GO.	
	52	Launch Pad Supervisor confirm Meteorological Tower personnel are under cover.	
	53	Launch Pad Supervisor confirm that vehicle arm and disarm checks completed.	
00-03-00	54	Time Count.	
00-02-00	55	Time Count.	
00-01-00	56	Telemetry tape recorders ON.	
00-00-50	57	Time Count.	
00-00-40	58	Time Count.	
00-00-30	59	HOLD COUNT.	

T-MINUS: (Hr-Min-Sec)	ITEM	OPERATION
00-00-30 (Cont.)	60	Upon command from the Test Director the Launch Pad Supervisor shall:
		1. Manually pull vehicle ignition circuits charging cable.
		2. Manually pull vehicle external ignition short.
	61	Clear launch area.
	62	Launch Pad Supervisor arm vehicle ignition circuits (verify via Channel No. 2).
00-00-30 (and counting)	63	Resume count.
	64	Uncage gyros.
	65	Telemetry paper recorders ON at speed of 1.0 ips.
00-00-25	66	Time Count.
00-00-20	67	Time Count.
00-00-15	68	Time Count.
00-00-10	69	Verbal count in one-second internals to T+10 seconds.
	70	Increase T/M paper recorder speed to 10 ips.
00-00-09	71	Time Count.
00-00-08	72	Time Count.
00-00-07	73	Time Count.
00-00-06	74	Time Count.
00-00-05	75	Time Count.
00-00-04	76	Time Count.

T-MINUS: (Hr-Min-Sec)	ITEM	OPERATION
00-00-03	77	Time Count.
00-00-02	78	Time Count.
00-00-01	79	Bomb tone ON (3105 KC AM)
00-00-00	80	Bomb tone OFF.
	81	First-stage Aerojet Junior ignites.
	82	Two Recruits fire through Maypole circuit.
	83	Payload instrumentation and vehicle monitor circuits disconnected at flyaway.

T-PLUS: (Hr-Min-Sec)		
00-00-01	84	Time Count.
00-00-02	85	Two Recruits burn out and remain attached to first stage.
00-00-03	86	Time Count.
00-00-04	87	Time Count.
00-00-05	88	Time Count.
00-00-06	89	Time Count.
00-00-07	90	Time Count.
00-00-08	91	Time Count.
00-00-09	92	Time Count.
00-00-10	93	Verbal time count given at 5-second intervals until T+120 seconds.
00-00-40	94	First-stage Aerojet Junior burns out and remains attached to second stage (altitude - 119,043 feet; velocity - 6,153 ft/sec).

T-PLUS: (Hr-Min-Sec)	ITEM	OPERATION
00-00-48	95	Four spin rockets, mounted within the interstage assembly, fire and spin-up the second stage and payload to 10 r/s inside the clamshell. Rotation releases explosive bolt timer.
00-00-49	96	Explosive bolts fire at 49.5 seconds to release Marman clamp. Clamshell opens.
00-00-50	97	Second-stage Alcor ignites and blast separates the first stage (altitude - 174,984 feet; velocity - 5,829 fps).
00-01-00	98	Time Count.
00-01-20	99	Second-stage Alcor burns out and remains with payload (altitude - 459,028 feet; velocity - 18,424 fps).
00-01-40	100	T/M paper recorders to 1.0 ips.
00-05-00	101	Release postflight theodolite balloon.
00-10-00	102	Squib actuated pin pullers release first yo-yo despin system. Payload despins from 12.5 r/s to 9 r/s.
00-15-00	103	Squib actuated pin pullers release second yo-yo despin system to despin payload from 9 r/s to 6 r/s.
00-16-15	104	Apogee (altitude - 7,184,886 feet; horizontal range - 715 nautical miles).
00-31-22	105	Impact (range - 1,407 nautical miles).